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NEW CHAPTERS IN THE WARFARE OF SCIENCE.

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I. THE DOCTRINE OF COMETS.

IN all the development of astronomy few things are more interesting than the growth of a true doctrine of comets. Hardly anything throws a more vivid light upon the danger of using isolated texts of Scripture to preserve beliefs which observation and thought have superseded, and upon the folly of arraying ecclesiastical power against scientific discovery.

Out of the ancient world had come a mass of beliefs regarding comets, meteors, and eclipses; these were universally held to be portents sent directly from heaven for the warning of mankind. As to stars and meteors, they were generally thought to presage happy events, especially births of gods, heroes, and great men. So firmly rooted was this idea that we constantly find among the ancient nations notices of lights in the heavens heralding the birth of persons of note. The sacred books of India show that the births of Crishna* and of Buddha† were announced by such heavenly lights. The sacred books of China reveal similar appearances at the births of Yu, the founder of the first dynasty, and of the inspired sage Lao-tse.‡ In the Jew-

* For stars at the birth of Crishna, see Maurice's "History of Hindostan," vol. ii, p. 336; also Cox's "Aryan Mythology" (London, 1870), vol. ii, p. 133; also "Vishnu Purana," Wilson's translation, b. v, chap. iii.

† For lights at the birth, or rather conception, of Buddha, see Bunsen's "Angel Messiah," pp. 22, 23–33; also, Alabaster, "Wheel of the Law," illustrations of Buddhism (London, 1871), p. 102; also, Edwin Arnold's "Light of Asia" (London, 1881), p. 3; also, "Life of Gaudama, the Burmese Buddha," by Bishop Bigandet (London, 1880), p. 30; also, Oldenberg's "Buddha," English translation, part i, chap. i.

‡ For Chinese legends regarding stars at the births of Lao-tse and Yu, see Horton's "History of China," i, 137.

ish legends a star appeared at the birth of Moses,* and was seen by the Magi of Egypt,† who informed the king; and when Abraham was born an unusual star appeared in the east. The Greeks and Romans held similar traditions.‡ A heavenly light accompanied the birth of Æsculapius, and the births of various Cæsars were heralded in like manner.

As to the nature of these heavenly bodies, the fathers of the Christian Church were divided. Origen thought them living creatures possessed of souls, and the belief was thought warranted by the beautiful Song of the Three Children which the Anglican communion has so wisely retained in its liturgy. Other fathers of the Church thought the stars abiding-places of the angels, and that shooting-stars were moved by angelic hands. Philo Judæus believed the stars beneficent spirits, and this belief was widely held by Jews, Greeks, and Christians. Among the Mohammedans we have curious examples of the same tendency toward a kindly interpretation of stars and meteors, in the belief of certain Mohammedan teachers that meteoric showers are caused by good angels hurling missiles to drive evil angels out of the sky.#

As to eclipses, they were regarded in a very different light, and were supposed to express the distress of Nature at earthly calamities. The Greeks believed that darkness overshadowed the earth at the

* As to traditions regarding stars at the births of Moses and Abraham, see Calmet's "Fragments," part viii; also, the Rev. Baring-Gould's "Legends of Old Testament Characters" (London, 1871), chap. xxiv; also, Farrar's "Life of Christ" (American edition), chap. iii.

† For the general subject, see Higgins's "Anacalypsis"; also, Hooykaas, Ort and Kuehnen (the Bible for learners), vol. iii.

‡ For similar appearances in Greece and Rome, see Bell's "Pantheon," article "Æsculapius"; also, Luc. i, 529; Suet. Cæs., 88; Seneca, "Nat. Quæst.," i, 1; Virgil's "Eclogues," 9, 47.

As to movement of stars by angels, see Leopardi, "Errori Popolari."

As to the feeling of the fathers, see Origen's "De Principiis," vol. i, p. 129; also Philo Judæus.

As to meteoric showers caused by struggles between good and bad angels, see Watson and Guillemin on Comets.

For Atreus, *et al.*, see Cox's "Tales of Ancient Greece," pp. 41, 61, 62; Higgins's "Anacalypsis," vol. i, p. 322; Bell's "Pantheon," article "Atreus."

For the legend regarding darkness at the death of Romulus, see Higgins, vol. i, pp. 616, 617.

For legends regarding portents at the birth, death, and downfall of the Cæsars, see Suetonius, Vit. xii Cæs., cap. xxxvi; also, Josephus, book xiv, chap. xii, and note.

Also, for these and similar cases, see Virgil, Ovid, Pliny, and other Roman historians and poets; also, Higgins, as above; Gibbon's "Rome," vol. i, pp. 159, 590; Farrar's "Life of Christ," p. 52.

On Nero, see Tacitus's "Annals," book xiv, chap. xxii.

For portents at the death of Charles I, see sermon preached before Charles II, cited in Lecky's "History of England in the Eighteenth Century," vol. i, p. 65.

For the belief in general, see Leopardi, "Errori Popolari," cap. xi.

For eclipses, Phra Rahu, *et al.*, see Alabaster, "Wheel of the Law," p. 11.

deaths of Prometheus, Atreus, Hercules, Æsculapius, and Alexander the Great. The Roman legends held that, at the death of Romulus, there was darkness for six hours. The lives of the Cæsars give portents of all three kinds; for, at the death of Julius, the earth was shrouded in darkness, the birth of Augustus was heralded by a star, and the downfall of Nero by a comet. Nor has this mode of thinking ceased in modern times. A similar claim was made at the execution of Charles I, and Increase Mather thought an eclipse in Massachusetts an evidence of the grief of Nature at the death of President Chauncey, of Harvard College.* Traces of this feeling have come down to our own times. The beautiful story of the sturdy Connecticut statesman who, when his associates in the General Assembly were alarmed by a general eclipse, and thought it the beginning of the day of judgment, ordered in candles, purposing in any case to be found doing his duty, marks probably the last noteworthy effect of the old belief in the civilized world.

In these beliefs regarding meteors and eclipses there was little calculated to do harm by arousing that superstitious terror which is the worst breeding-bed of cruelty. Far otherwise was it with the beliefs regarding comets. During many centuries they brought terrors which developed the direst superstition and fanaticism; the ancient records of every continent are full of these. One great man, indeed, in the Roman Empire had the scientific instinct and prophetic inspiration to foresee that at some future time the course of comets would be found in accordance with natural law.† But this thought of Seneca was soon forgotten; such an isolated utterance could not stand against the mass of superstition which upheld the doctrine that comets are "signs and wonders." The belief that every comet is a ball of fire, flung from the right hand of an angry God to warn the groveling dwellers of earth, was received into the early Church, transmitted through the middle ages to the Reformation period,‡ and in its transmission and reception was made all the more precious by supposed textual proofs from Scripture. The great fathers of the Church committed themselves unreservedly to this doctrine. Tertullian# declared that "comets portend revolutions of kingdoms, pestilence, war, winds, or heat." Origen‖ insisted that they indicate "catastrophes and the downfall of empires and worlds." The Venerable Bede,^ so justly dear to the English Church, made in the ninth

* He thought, too, that it might have something to do with the deaths of sundry civil functionaries of the colony. See his discourse concerning comets, 1682.

† See Watson "On Comets," p. 46, with Glaisher's translation of Seneca's prediction.

‡ For this feeling in antiquity see Guillemin, "The World of Comets," translated by Glaisher, chaps. i and ii; also Watson "On Comets," preliminary chapters.

For Tertullian, see "Ad Scapul," 3.

‖ For Origen, see "De Principiis," i, 754; also Maury, "Legendes pieuses du Moyen Age," p. 203, and note.

^ For Bede, see his "De Natura Rerum," chap. xxiv.

century a similar declaration. St. Thomas Aquinas,* the great light of the universal Church in the thirteenth century, whose works the Pope now reigning commends as the center of all university instruction, accepted and handed down the same opinion. The sainted Albert the Great,† the most noted genius of the mediæval Church in natural science, received and developed this theory.

By these men a science was developed out of scriptural texts and the principles of morals, and so firmly rooted in Scripture and theology that it flourished for seventeen centuries.

The main evils thence arising were two: First, the paralysis of self-help, and the arousing of fanaticism; and, secondly, the strengthening of ecclesiastical and political tyranny.

As to the first of these evils—the paralysis of self-help—instead of wise statesmanship striving to avert war, instead of scientific observation and reason striving to avert pestilence, instead of social science taking proper measures against famine, we constantly see, at the appearance of a comet, all Christendom, from pope to peasant, whining before various fetiches, trying to bribe them to remove these signs of God's wrath, and planning to wreak this supposed wrath of God upon misbelievers.

As to the second of these evils—the strengthening of ecclesiastical and civil despotism—examples appear on every side. It was natural that hierarchs and monarchs whose births were announced by stars, or whose deaths were announced by comets, should regard themselves as far above the common herd, and be so regarded by mankind; that passive obedience should thus be strengthened, and that the most monstrous assumptions of authority by such men should be considered simply as manifestations of the divine will. Shakespeare makes Calphurnia say to Cæsar:

> "When beggars die, there are no comets seen;
> The heavens themselves blaze forth the death of princes."‡

Galeazzo, tyrant of Milan, expressing satisfaction on his death-bed that his approaching end was of such importance as to be heralded by a comet, is a type of many thus encouraged to prey upon mankind.*

But, for the retention of this belief, there was a moral cause. No doubt myriads of good men in the Christian Church, down to a recent period, saw in the appearance of comets not merely an exhibition of "signs in the heavens" foretold in Scripture, but also divine warnings to repentance and improvement of life of vast value to humanity—warnings, indeed, so precious that they could not be dispensed with

* For St. Thomas Aquinas, see Maury, "La Magie et l'Astronomie," p. 181.

† For Albert the Great, see "Alb. Mag.," lib. i, tract. iii, chaps. x and xi; also ibid., "Super sex principiis Gilberti Porretani"; also "Tractatus primus de causis impressionum," etc. The copy I have used is in the Cornell University Library.

‡ "Julius Cæsar," act ii, scene ii.

* For Galeazzo, see Guillemin "On Comets."

without danger to the moral government of the world. Reasons, then, partly scriptural, partly theological, led men to cherish the belief in the portentous character of comets as absolutely essential, religiously and morally. To say nothing of the many examples in the earlier mediæval period, comets in the tenth century strengthened the belief in the approaching end of the world, and increased the distress and terror of all Europe. The charters of that age constantly refer to this. In the middle of the eleventh century a comet was thought to accompany the death of Edward the Confessor, and to presage the Norman Conquest; the traveler in France to-day may see this belief as it was then wrought in the Bayeux tapestry.*

Nearly every decade of years saw Europe plunged into alarm by appearances of this sort; but the culmination was reached in 1456. At that time, the Turks, after ages of effort, had made good their footing in Europe. A large statesmanship or generalship might have kept them out; but, while different religious factions were disputing over petty shades of dogma, the Turks had advanced, had taken Constantinople, and were pressing on to secure their foothold in Europe. Now came the full bloom of this superstition. A comet appeared. The Pope of that period, Calixtus III, was a man of more than ordinary ability, but saturated with the ideas of his time. By virtue of his position as the infallible head of Christendom, he publicly and solemnly anathematized both the Turks and the comet, bidding all the faithful beseech the Almighty to turn the monster in the heavens away from the Christians and against the Turks. In the litany was incorporated the prayer, "From the Turk and the comet, good Lord deliver us." Thence, it is generally supposed, dates the midday *Angelus*, the bell calling the faithful to prayer against the powers of evil.

Never was the object of a papal fulmination more unfortunately chosen; for the Turk has held Constantinople from that day to this, and the comet, being that now known under the name of Halley, so far from heeding the infallible anathema, has returned imperturbably at short periods ever since.†

* For effects of comets in the eleventh and following centuries, see "Chronicles" of Raoul Glaber, William of Nangis, and others *passim*.

For the Bayeux tapestry, see Bruce, "Bayeux Tapestry elucidated" (London, 1856), Plate VII, and text, p. 86; also Guillemin, p. 24; also Champion, p. 89. This tapestry, wrought by the wife of William the Conqueror and her ladies, is now preserved in the town museum of Bayeux.

† The usual statement is that Calixtus excommunicated the comet by a papal bull. A statement to this effect is made by such authorities as Arago, Guillemin, Watson, and many others; and this suggested the shrewd parallel made on a noted occasion by President Lincoln. An examination of various *Bullaria* has as yet failed to discover any formal bull; and, though this by no means proves that such a bull was not issued, it is most likely that the utterance of the Pope was in the nature of a general anathema, an appeal to Christian peoples against the comet, as stated in the "Historia B. Platinæ de vitis Pontificum, Coloniæ, MDC.," p. 317, for which I am indebted to Dr. Gilette, Librarian of the Union Theological Seminary, New York.

But this superstition went still further. It became more and more incorporated into what was considered "scriptural science" and "sound learning." The encyclopedic statements exhibiting the science of the middle ages and the Reformation period furnish abundant proofs of this.*

Yet scientific truth was slowly undermining the structure: the inspired prophecy of Seneca had not been forgotten: even as far back as the ninth century, in the midst of the "sacred learning" so abundant at the court of Charlemagne and his successors, we find a scholar protesting against the doctrine.†

So, too, in the sixteenth century we have Paracelsus writing to Zwingle against it; and, in the century following, men like De Gamon and Pierre Petit taking similar ground.‡

At first this skepticism only aroused the horror of theologians and increased the vigor of ecclesiastics; both asserted all the more strenuously what they conceived to be scriptural truth. During the sixteenth century France felt the influence of one of her greatest men on the side of this superstition. Jean Bodin, so far before his time in political theories, was as far behind it in religious theories: the same reverence for the mere letter of Scripture which made him so fatally powerful in supporting the witchcraft delusion led him to support this theological theory of comets; but with a difference—he thought them the souls of men wandering in space, bringing famine, pestilence, and war.*

In England, too, during the sixteenth and seventeenth centuries, there was at least literary acquiescence in this received doctrine of comets. Both Shakespeare and Milton recognize it, whether they fully accept it or not. Shakespeare makes the Duke of Bedford, lamenting at the bier of Henry V, say:

> "Comets, importing change of times and states,
> Brandish your crystal tresses in the sky;
> And with them scourge the bad revolting stars,
> That have consented unto Henry's death."

Milton, speaking of Satan preparing for combat, says:

> ". . . On the other side,
> "Incensed with indignation, Satan stood
> Unterrified, and like a comet burned,
> That fires the length of Ophiuchus huge
> In the Arctic sky, and from its horrid hair
> Shakes pestilence and war."

* See Vincent de Beauvais, and the various editions of Reisch's "Margarita Philosophica."

† See Champion, p. 156; also Leopardi, "Errori Popolari," p. 165.

‡ For these exhibitions of skepticism, see Champion, pp. 155, 156.

* See Champion, p. 89; also a vague citation in Baudrillart, "Vie de Bodin," p. 360.

Even as late as the end of the seventeenth century (1688) we have English authors of much power battling for this supposed scriptural view.

But it was in Germany that this superstition took its strongest hold. The same depth of feeling which produced in that country the most terrible growth of the witchcraft persecution brought superstition to its highest development regarding comets. In one of his Advent sermons, Luther had declared strongly in favor of it. A little later Arietus declared, "The heavens are not merely given us for our pleasure, but also as a warning for the correction of our lives, and of the wrath of God."* Lavather showed that comets are signs of death or calamity, and cited proofs from Scripture. Catholic and Protestant strove together for the glory of asserting the doctrine, and in the same seventeenth century Fromundus, the eminent Professor and Doctor of Theology at the University of Louvain, who so strongly opposed the rotundity of the earth, supported no less vigorously the prophetic character of comets. So, too, as late as 1680, we have Voigt declaring that the comet of that year clearly presages the downfall of the Turkish Empire, and stigmatizing as "atheists and epicureans" all who do not believe comets to be God's warnings.†

But the great efforts in behalf of this doctrine throughout Europe were made in the pulpits, and especially in the Protestant pulpits. Out of the mass of such sermons which were widely circulated, I will select just one as typical, and it is worthy of careful study, as showing the dangers of applying theological methods to scientific fact. Conrad Dieterich was during the first half of the seventeenth century a Lutheran ecclesiastic of the highest authority. His ability as a theologian had made him Archdeacon of Marburg, Professor of Philosophy and director of studies at the University of Giessen, and finally "Superintendent," exercising functions of an episcopal character in the Lutheran regions of Southwestern Germany. In the year 1620, on the second Sunday in Advent, in the great Cathedral of Ulm, he developed the orthodox doctrine of comets in a sermon, taking up the questions: 1. What are comets? 2. What do they indicate? 3. What have we to do with their significance? This sermon marks an epoch. Delivered in that center of Protestant Germany, and by a prelate of the highest standing, it was immediately printed, prefaced by three laudatory poems from different men of note, and sent forth to drive back the scientific, or, as it was supposed, the "godless," view of comets. The preface shows that Dieterich was sincerely alarmed by the tendency to regard comets as natural appearances. His text was taken from the twenty-fifth verse of the twenty-first chapter of St. Luke: "And there shall be signs in the sun, and in the moon, and in

* See Mädler, "Geschichte der Astronomie," vol. ii.

† For Fromundus and Voigt, see Mädler, p. 399; also Lecky, "Rationalism in Europe," vol. i, p. 28.

the stars; and upon the earth distress of nations, with perplexity; the sea and the waves roaring." As to what comets are, he cites a multitude of ancient philosophers, and, finding that they differ among themselves, he uses a form of argument very common from that day to this, declaring that this difference of opinion proves that there is no solution of the problem save in revelation, and insisting that they are "signs especially sent by the Almighty to warn the earth." An additional proof of this he finds in the forms of comets. One, he says, took the form of a trumpet; another, of a spear; another, of a goat; another, of a torch; another, of a sword; another, of an arrow; another, of a saber; still another, of a bare arm; and so on. From these forms of comets he infers that we may divine their purpose. As to their creation, he quotes John of Damascus and other great church authorities in behalf of the idea that each comet is a star newly created at the divine command out of nothing, and that it indicates the wrath and punishment of God. As to their purpose, having quoted largely from the Bible and from Luther, he winds up by insisting that, as God can make nothing in vain, comets must have some distinct object: then from Isaiah and Joel among the prophets, from Matthew, Mark, and Luke among the Evangelists, from Origen and St. John Chrysostom among the fathers, from Luther and Melanchthon among the Reformers, he draws various texts more or less conclusive to prove that comets indicate evil and only evil, and he cites Luther's Advent sermon, to the effect that, though comets may arise in the course of nature, they are still signs of evil to mankind.

In answer to the theory of certain naturalists, that comets are made up of "a certain fiery, warm, sulphurous, saltpetery, sticky fog," he declares, "Our sins, our sins! they are the fiery heated vapors, the thick, sticky, sulphurous clouds which rise from the earth toward heaven before God."

Throughout the sermon contempt was poured over all men who simply investigated comets as natural objects, and special attention was called to the fact that a comet then in the heavens resembled a long broom or bundle of rods; and Dieterich declared that he and his hearers would only consider it rightly "when we see standing before us our Lord God in heaven as an angry father with a rod for his children."

In answer to the question, what comets signify, he commits himself entirely to the idea that they indicate the wrath of God, and therefore calamities of every sort. Page after page is filled with the record of evils following comets. Beginning with the creation of the world, he insists that the first comet brought on the deluge of Noah. He cites a mass of authorities ranging from Moses and Isaiah to Albert the Great and Melanchthon, in support of the view that comets precede earthquakes, famines, wars, pestilences, and every form of evil. Page after page is filled with this sort of historical proof. He

makes some parade of astronomical knowledge as to the greatness of the sun and moon, but relapses soon into his old line of argument. Conjuring his audience not to be led away from the well-established belief of Christendom and the principles of their fathers, he comes back to his old figure of speech, insists that "our sins are the inflammable material of which comets are made," and winds up with a most earnest appeal to the Almighty to spare his people.*

It can be easily understood that such an authoritative utterance as this must have produced a great effect throughout Protestant Christendom, and in due time we see its working in New England. That same tendency to provincialism which, save at rare intervals, has been the bane of Massachusetts thought from that day to this, appeared; and in 1664 we have Samuel Danforth arguing from the Bible that comets are "portentous signals of great and notable changes," and arguing from history that they "have been many times heralds of wrath to a secure and impenitent world." He cites especially the comet of 1652, which appeared just before Mr. Cotton's sickness, and disappeared after his death.† Morton also, in his memorial, recording the death of John Putnam, alludes to the comet of 1652 as "a very signal testimony that God had then removed a bright star and a shining light out of the heaven of his church here into celestial glory above."‡ Again he speaks of another comet, insisting that "it was no fiery meteor caused by exhalation, but it was sent immediately by God to awaken the secure world," and goes on to show how in that year "it pleased God to smite the fruits of the earth, namely, the wheat in special, with blasting and mildew, whereby much of it was spoiled and became profitable for nothing, and much of it worth little, being light and empty. This was looked upon by the judicious and conscientious of the land as a speaking providence against the unthankfulness of many . . . as also against voluptuousness and abuse of the good creatures of God by licentiousness in drinking and fashions in apparel, for the obtaining whereof a great part of the principal grain was oftentimes unnecessarily expended."#

But in 1680 a stronger man than either of these seized upon the doctrine and wielded it with power. Increase Mather, so open always to ideas from Europe, and always so powerful for good or evil in the

* See "Ulmische Cometen Predigt, von dem Cometen, so nechst abgewischenen 1618 Jahrs im Wintermonat erstenmahls in Schwabensen lassen, Dannach folgende Gehalten zu Ulm," etc. Durch Conrad Dieterich, Ulm, 1620.

For a life of the author of the book, see article, "Dieterich," in the "Allgemeine Deutsche Biographie."

† See S. Danforth (1664), "An Astronomical Description of the late Comet or Blazing Star, together with a Brief Theological Application thereof." (Collections in the Massachusetts Historical Society Library.)

‡ See Morton's "Memorial," pp. 251, 252.

Ibid., pp. 309, 310.

colonies, preached his sermon on "Heaven's Alarm to the World, . . . wherein is shown that fearful sights and signs in the heavens are the presages of great calamities at hand." The texts were taken from the book of Revelation: "And the third angel sounded, and there fell a great star from heaven, burning as it were a lamp"; also, "Behold, the third woe cometh quickly."*

In this as in various other sermons he supported the theological cometary theory, fully. He insists that "we are fallen into the dregs of time," and that the day of judgment is evidently approaching. He explains away the words of Jeremiah, "Be not dismayed at signs in the heavens," and shows that comets have been forerunners of nearly every form of evil. Having done full justice to evils thus presaged in scriptural times, he begins a similar display in modern history by citing blazing stars which foretold the invasions of Goths, Huns, Saracens, and Turks, and warns gainsayers by citing the example of Vespasian, who, after ridiculing a comet, soon died. The general shape and appearance of comets, he thinks, betoken their purpose, and cites Tertullian to prove them "God's sharp razors on mankind whereby he doth poll, and his scythe whereby he doth shear down multitudes of sinful creatures." At last, rising to a fearful height, he declares: "For the Lord hath fired his beacon in the heavens among the stars of God there; the fearful sight is not yet out of sight. The warning piece of heaven is going off. Now then if the Lord discharge his murdering pieces from on high, and men be found in their sins unfit for death, their blood shall be upon them." And again, in an agony of supplication, he cries out: "Do we see the sword blazing over us? Let it put us upon crying to God, that that judgment be diverted and not return upon us again so speedily. . . . Doth God threaten our very heavens? O pray unto Him, that He would not take away stars and send comets to succeed them."†

But even in the midst of all his arguments appears an evident misgiving. The thoughts of Newton in science and Bayle in philosophy were evidently tending to accomplish the prophecy of Seneca. Mather's alarm at this is clear. His natural tendency is to uphold the idea that a comet is simply a fire-ball flung from the hand of an avenging God at a guilty world, but he evidently feels obliged to yield something to the scientific spirit; hence, in the discourse concerning comets, published in 1682, he declares: "There are those who think that, inasmuch as comets may be supposed to proceed from natural causes, there is no speaking voice of heaven in them beyond what is to be said of all other works of God. But certain it is that many things which may happen according to the course of nature are portentous signs of divine anger and prognostics of great evils hastening upon the world."

* Rev. viii, 10, and xi, 14.

† See "Heaven's Alarm to the World," Boston, 1682. (In President Sparks's collection, Cornell University Library.)

He then notices the eclipse of August, 1672, and adds: "That year the college was eclipsed by the death of the learned president there, worthy Mr. Chauncey; and two colonies, namely, Massachusetts and Plymouth, by the death of two governors, who died within a twelvemonth after. . . . Shall, then, such mighty works of God as comets are be insignificant things?"

Vigorous as his argument is, we see skepticism regarding "signs" continuing to invade the public mind; and, in spite of his threatenings, about twenty years after, we find a remarkable evidence of this progress in the fact that this skepticism has seized upon no less a personage than that colossus of orthodoxy, his thrice illustrious son, Cotton Mather himself; and him we find, in 1726, despite the arguments of his father, declaring in his "Manuductio": "Perhaps there may be some need for me to caution you against being dismayed at the signs of the heavens, or having any superstitious fancies upon eclipses and the like. . . . I am willing that you be apprehensive of nothing portentous in blazing stars. For my part, I know not whether all our worlds, and even the sun itself, may not fare the better for them."*

Curiously enough, for this scientific skepticism in Cotton Mather, there was a cause identical with that which had developed superstition in the mind of his father. The same provincial tendency to receive implicitly any new idea from abroad wrought upon both, plunging one into superstition and drawing the other out of it. First among the more important reasonings against the prevailing superstition were those of Gassendi. Early in the seventeenth century, by strictly scientific process, he arrived at the conclusion that comets are outside the earth's atmosphere, and then made a strong argument from common sense that there is nothing to prove them hostile to the happiness of mankind.†

But, toward the end of the same century, the subject was taken up by Pierre Bayle. He attacked the old theory from the side of philosophy. While professor at the University of Sedan he had observed the alarm caused by the comet of 1680, and he now brought all his reasoning powers to bear upon it. Thoughts deep and witty he poured out in volume after volume; Catholics and Protestants were alike scandalized: Catholic France spurned him, and Jurieu, the great reformed divine, tried hard to have Protestant Holland do likewise. Though Bayle did not touch immediately the mass of mankind, he wrought with power upon men who gave themselves the trouble of thinking. It was indeed unfortunate for the Church that theologians, instead of taking the initiative in this matter, left it to Bayle; for, in tearing down the pretended scriptural doctrine of comets, he tore down much else: of all men in his time, no one so thoroughly prepared the way for Voltaire.

* See "Manuductio," pp. 54, 55.

† For Gassendi, see Mädler, ii, 397, and Champion, 93–95.

The whole argument of Bayle is rooted in the prophecy of Seneca. He declares, "Comets are bodies subject to the ordinary law of nature, and not prodigies amenable to no law." He shows historically that there is no reason to regard comets as portents of earthly evils. As to the fact that such evils occur after the passage of comets across the sky, he compares the person believing that comets cause these evils to a woman looking out of a window into a Paris street, and believing that the carriages pass because she looks out. As to the accomplishment of some predictions, he cites the shrewd saying of Henry IV, to the effect that "the public will remember one prediction that comes true better than all the rest that have proved false"; finally, he sums up by saying: "The more we study man, the more does it appear that pride is his ruling passion, and that he affects grandeur even in his misery. Mean and perishable creature that he is, he has been able to persuade men that he can not die without disturbing the whole of nature and obliging the heavens to put themselves to fresh expense in order to light his funeral pomp. Foolish and ridiculous vanity! If we had a just idea of the universe, we should soon comprehend that the death or birth of a prince is too insignificant a matter to stir the heavens." *

This great philosophic champion of right reason was followed by a literary champion hardly less famous; for Fontenelle now gave to the French theatre his play of "The Comet," and a point of capital importance in France was made by rendering the army of ignorance ridiculous.†

But the heart of the position held by the so-called "religious" party was not really touched until about the beginning of the eighteenth century. Then it was that the announcement of Doerfel as to the parabolic paths of certain comets, and the publication of Halley's "Synopsis" and "Tables" foreshadowed a final victory, and the complete accomplishment of the prophecy of Seneca. This victory was fully gained when Halley, observing the times of the comet which now bears his name, made his calculations, predicted the period of its return, and the prediction was fulfilled.

Still more evident was this victory when Clairaut, in France, foretold the exact time when the coming comet would reach its perihelion, and his prediction also proved true. Then it was that a Roman heathen philosopher was proved more infallible and more directly under divine inspiration than a Roman Christian pontiff; for the very comet which the traveler finds to-day depicted on the Bayeux tapestry as portending destruction to Harold and the Saxons at the Norman inva-

* For special points of interest in Bayle's argument, see Bayle, "Pensées Diverses," Amsterdam, 1749, pp. 79, 102, 134, 206.

For the response to Jurieu, see "Continuation des Pensées Diverses," Rotterdam, 1705; also Champion, p. 164; also Lecky, as above; also Guillemin, pp. 29, 30.

† See Fontenelle, cited in Champion, p. 167.

sion of England, and which was anathematized by Pope Calixtus as portending evil to Christendom four centuries later, was found to be, as Seneca had prophesied, a heavenly body obeying the great laws of the universe, and coming at regular periods. Thenceforth the whole ponderous enginery of superstition, with its citations of proof-texts regarding "signs in the heavens," its theological reasoning to show the moral necessity of cometary warnings, and its ecclesiastical fulminations against the "atheism, godlessness, and infidelity" of scientific investigation, was seen by all thinking men to be as weak against the scientific method as Indian arrows against needle-guns. Copernicus, Galileo, Newton, Cassini, Doerfel, Halley, and Clairaut had gained the victory.*

And still even good men looked longingly back to the old belief. It was so hard for them to give up the doctrine of "signs in the heavens," seemingly based upon Scripture, and exercising such a healthful moral tendency! As is always the case under such circumstances, votaries of "sacred science" appeared, and these exerted the greatest ingenuity in averting the new doctrine; but their voices gradually died into silence, though far within our own century Joseph de Maistre echoed them in declaring his belief that comets are special warnings of evil.

There did, indeed, still linger one little cloud-patch of superstition, arising from the supposed fact that comets had really been followed by a marked rise in temperature. Even this poor basis for the belief that comets might, after all, affect earthly affairs was swept away. Science won here another victory, for Arago, by thermometric records carefully kept at Paris from 1735 to 1781, proved that comets had produced no effect upon temperature. Among multitudes of similar examples he showed that, in some years when several comets appeared, the temperature was lower than in other years when few or none appeared. In 1737 there were two comets, and the weather was cool; in 1765 there was no comet, and the weather was hot; through the whole fifty years it was shown that comets were sometimes followed by hot weather, sometimes by cool, and that no rule was deducible. The victory of science was complete at every point.†

But in this whole history there was one little exhibition so curious as to be worthy of notice, though its permanent effect upon thought was small. Whiston and Burnet, so devoted to what they considered sacred science, had determined that in some way comets must be instruments of divine wrath. One of them maintained that the deluge was caused by the tail of a comet striking the earth; the other

* See Mädler, as above; also, Guillemin, Watson, and Grant's "History of Astronomy"; also, Delambre, Proctor, article "Astronomy" in "Encyclopædia Britannica," and others.

† For the writings of several on both sides, and especially those who sought to save, as far as possible, the sacred theory of comets, see Mädler, ii, p. 384, *et seq.*

put forth the theory that comets are places of punishment for the damned—in fact, "flying hells." Both these theories were soon discredited.

Perhaps this theory can best be met by another which, if not fully established, appears much the better based of the two; namely, that in 1868 the earth passed directly through the tail of a comet, with no deluge, no sound of any wailings of the damned, with slight appearances here and there, only to be detected by the keen sight of the meteorological or astronomical observer.* In our own country superstitious ideas regarding comets continued to have some little currency;† but their life was short. The tendency shown by Cotton Mather, at the beginning of the eighteenth century, toward acknowledging the victory of science was completed by the utterances of Winthrop, professor at Harvard. In 1759 he published two lectures on comets, and in these he simply and clearly revealed the truth, never scoffing, but reasoning quietly and reverently. In one passage he says, "To be thrown into a panic whenever a comet appears, on account of the ill effects which some few of them might possibly produce, if they were not under proper direction, betrays a weakness unbecoming a reasonable being."‡

The victory was, indeed, complete. Happily, none of the fears expressed by Conrad Dieterich or Increase Mather were realized. No catastrophe has ensued either to religion or morals. In the realm of religion, the Psalms of David remain no less beautiful, the great utterances of the Hebrew prophets no less powerful; the Sermon on the Mount, "the first commandment and the second which is like unto it," the definition of "pure religion and undefiled," by St. James, appeal no less to the deepest things in the human heart. In the realm of morals, too, serviceable as the idea of fire-brands thrown by the right hand of an avenging God to scare a naughty world might seem, any competent historian must find that the destruction of the old theological cometary theory was followed by moral improvement rather than by deterioration. We have but to compare the general moral tone of society to-day, wretchedly imperfect as it is, with that existing in the time when this superstition had its strongest hold, to make ourselves sure of this. We have only to compare the court of Henry VIII with the court of Victoria, the reign of the late Valois and earlier Bourbon princes with the present French Republic, the period of the Medici and Sforzas and Borgias with the period of Leo XIII and Humbert, the monstrous wickedness of the Thirty Years' War with the ennobling patriotism of the Franco-Prussian struggle, and the

* See Guillemin and Watson.

† See sermon of Israel Loring, of Sudbury, published in 1722 (Professor M. C. Tyler's manuscript notes).

‡ See Professor J. Winthrop on comets (Professor Tyler's manuscript notes, pp. 15 and 16).

despotism of the miserable German princelings of the sixteenth and seventeenth centuries with the reign of the Emperor William.

The gain is not simply that mankind has arrived at a clearer conception of law in the universe; not merely that thinking men see more clearly that we are part of a system not requiring constant patching and arbitrary interference; but perhaps best of all is the fact that science has cleared away one more series of dogmas which tend to debase rather than to develop man's whole moral and religious nature. In this emancipation from terror and fanaticism, as in so many other results of scientific thinking, we have a proof of the inspiration of those great words, "THE TRUTH SHALL MAKE YOU FREE."

THE WHITE ANT: A THEORY.

BY PROFESSOR HENRY DRUMMOND, F. R. S. E., F. G. S.,
AUTHOR OF "NATURAL LAW IN THE SPIRITUAL WORLD," ETC.

A FEW years ago, under the distinguished patronage of Mr. Darwin, the animal in vogue with scientific society was the worm. At present the fashionable animal is the ant. I am sorry, therefore, to have to begin by confessing that the insect whose praises I propose to sing, although bearing the honored name, is not entitled to consideration on account of its fashionable connections, since the white ant, as an ant, is an impostor. It is, in fact, not an ant at all, but belongs to a much humbler family—that of the *Termitidæ*—and, so far from ever having been the vogue, this clever but artful creature is hated and despised by all civilized peoples. Nevertheless, if I mistake not, there is neither among the true ants, nor among the worms, an insect which plays a more wonderful or important part in nature.

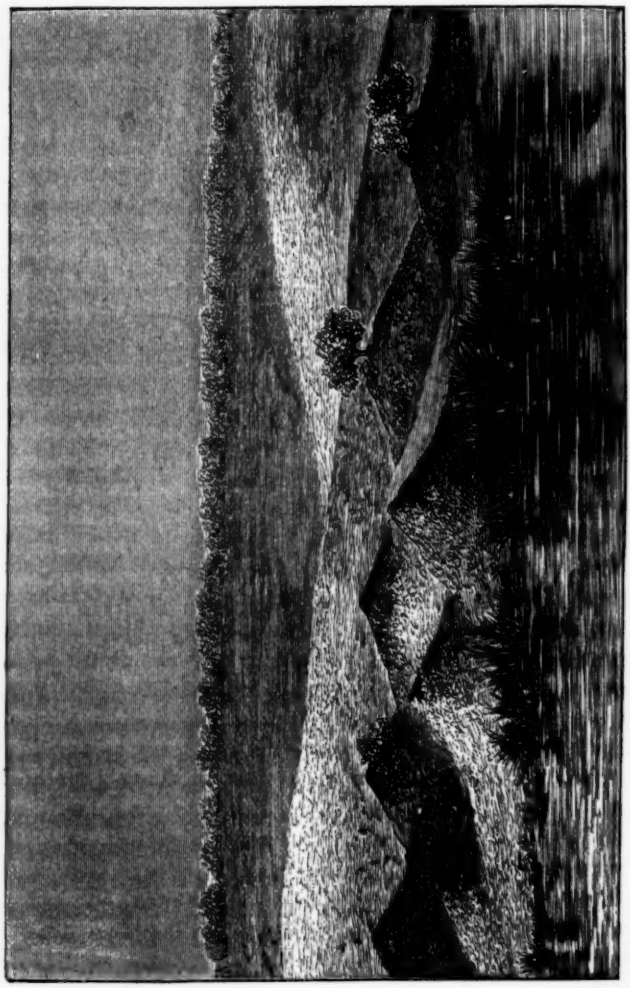
Fully to appreciate the beauty of this function, a glance at an apparently distant aspect of nature will be necessary as a preliminary.

When we watch the farmer at work, and think how he has to plow, harrow, manure, and humor the soil before even one good crop can be coaxed out of it, we are apt to wonder how Nature manages to secure her crops and yet dispense with all these accessories. The world is one vast garden, bringing forth crops of the most luxuriant and varied kind century after century, and millennium after millennium. Yet the face of Nature is nowhere furrowed by the plow, no harrow disintegrates the clods, no lime and phosphates are strewed upon its fields, no visible tillage of the soil improves the work on the great world's farm.

Now, in reality there can not be crops, or successions of crops, without the most thorough agriculture; and when we look more closely into nature we discover a system of husbandry of the most surprising

kind. Nature does all things unobtrusively ; and it is only now that we are beginning to see the magnitude of these secret agricultural operations by which she does already all that man would wish to imitate, and to which his most scientific methods are but clumsy approximations.

In this great system of natural husbandry Nature uses agencies, implements, and tools of many kinds. There is the disintegrating



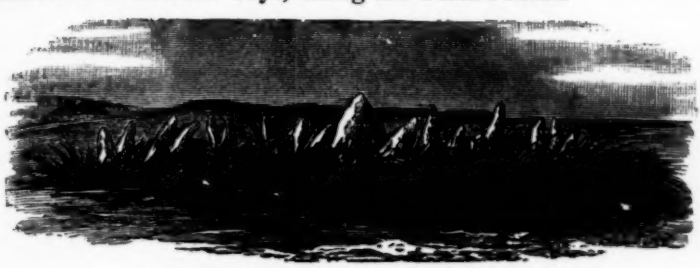
"THE MOUNDS OF THE WHITE ANT."

frost, that great natural harrow, which bursts asunder the clods by the expansion during freezing of the moisture imprisoned in their pores. There is the communistic wind which scatters broadcast over the fields the finer soil in clouds of summer dust. There is the rain which washes the humus into the hollows, and scrapes bare the rocks for further

denudation. There is the air which, with its carbonic acid and oxygen, dissolves and decomposes the stubborn hills, and manufactures out of them the softest soils of the valley. And there are the humic acids, generated through decay, which filter through the ground and manure and enrich the new-made soils.

But this is not all, nor is this enough; to prepare a surface film, however rich, and to manure the soil beneath, will secure one crop, but not a succession of crops. There must be a mixture and transference of these layers, and a continued mixture and transference kept up from age to age. The lower layer of soil, exhausted with bringing forth, must be transferred to the top for change of air, and there it must lie for a long time, increasing its substance, and recruiting its strength among the invigorating elements. The upper film, restored, disintegrated, saturated with fertility and strength, must next be slowly lowered down again to where the rootlets are lying in wait for it, deep in the under soil.

Now, how is this last change brought about? Man turns up the crust with the plow, throwing up the exhausted earth, down the refreshed soil, with infinite toil and patience. And Nature does it by natural plowmen who, with equal industry, are busy all over the world reversing the earth's crust, turning it over and over from year to year, only much more slowly and much more thoroughly spadeful by spadeful, foot by foot, and even grain by grain. Before Adam delved the garden of Eden these natural agriculturists were at work, millions and millions of them in every part of the globe, at different seasons and in different ways, tilling the world's fields.



"STANDING OUT AGAINST THE SKY LIKE OBELISKS."

According to Mr. Darwin, the animal which performs this most important function in nature is the earth-worm. The marvelous series of observations by which the great naturalist substantiated his conclusion are too well known for repetition. Mr. Darwin calculates that on every acre of land in England more than ten tons of dry earth are passed through the bodies of worms and brought to the surface every year: and he assures us that the whole soil of the country must pass and repass through their bodies every few years. Some of this earth is brought up from a considerable depth beneath the soil, for in order to make its subterranean burrow the animal is compelled to swallow a

certain quantity of earth. It eats its way, in fact, to the surface, and there voids the material in a little heap. Although the proper diet of worms is decaying vegetable matter, dragged down from the surface in the form of leaves and tissues of plants, there are many occasions on which this source of aliment fails, and the animal has then to nourish itself by swallowing quantities of earth, for the sake of the organic substances it contains. In this way the worm has a twofold inducement to throw up earth: First, to dispose of the material excavated from its burrow; and, second, to obtain adequate nourishment in times of famine. "When we behold a wide, turf-covered expanse," says Mr. Darwin, "we should remember that its smoothness, on which so much of its beauty depends, is mainly due to all the inequalities having been slowly leveled by worms. It is a marvelous reflection that the whole of the superficial mold over any such expanse has passed, and will again pass, every few years, through the bodies of worms. The plow is one of the most ancient and most valuable of man's inventions; but long before he existed the land was, in fact, regularly plowed by earth-worms. It may be doubted whether there are many other animals which have played so important a part in the history of the world as have these lowly organized creatures." *

Now, without denying the very important contribution of the earth-worm in this respect, a truth sufficiently indorsed by the fact

"SINGLY OR IN CLUSTERS."

that the most circumstantial of naturalists has devoted a whole book to this one animal, I would humbly bring forward another claimant to the honor of being, along with the worm, the agriculturist of na-

* "Vegetable Mold and Earth-worms," p. 313.

ture. While admitting to the fullest extent the influence of worms in countries which enjoy a temperate and humid climate, it can scarcely be allowed that the same influence is exerted, or can possibly be exerted, in tropical lands. No man was less in danger of taking a provincial view of nature than Mr. Darwin, and in discussing the earth-worm he has certainly collected evidence from different parts of the globe. He refers, although sparingly, and with less than his usual wealth of authorities, to worms being found in Iceland, in Madagascar, in the United States, Brazil, New South Wales, India, and Ceylon. But his facts, with regard especially to the influence on the large scale of the worm in warm countries, are few or wholly wanting. Africa, for instance, the most tropical country in the world, is not referred to at all; and, where the activities of worms in the tropics are described, the force of the fact is modified by the statement that these are only exerted during the limited number of weeks of the rainy season.

The fact is, for the greater portion of the year in the tropics the worm can not operate at all. The soil, baked into a brick by the burning sun, absolutely refuses a passage to this soft and delicate animal. All the members of the earth-worm tribe, it is true, are natural skewers, and, though boring is their supreme function, the substance of these skewers is not hardened iron, and the pavement of a tropical forest is quite as intractable for nine months in the year as are the frost-bound fields to the farmer's plowshare. During the brief period of the rainy season worms undoubtedly carry on their function in some of the moister tropical districts; and in the sub-tropical regions of South America and India worms, small and large, appear with the rains in endless numbers. But on the whole the tropics proper seem to be poorly supplied with worms. In Central Africa, though I looked for them often, I never saw a single worm. Even when the rainy season set in, the closest search failed to reveal any trace either of them or of their casts. Nevertheless, so wide is the distribution of this animal that in the moister regions even of the equatorial belt one should certainly expect to find it. But the general fact remains. Whether we consider the comparative poorness of their development, or the limited period during which they can operate, the sustained performance of the agricultural function by worms, over large areas in tropical countries, is impossible.

Now, as this agricultural function can never be dispensed with, it is more than probable that Nature will have there commissioned some other animal to undertake the task. And there are several other animals to whom this difficult and laborious duty might be intrusted. There is the mole, for instance, with its wonderful spade-like feet, that natural navvy who shovels the soil about so vigorously at home; but against the burned crust of the tropics even this most determined of burrowers would surely turn the edge of his nails. The same remark

applies to those curious little geologists, the marmots and chipmunks, which one sees throwing up their tiny heaps of sand and gravel on the American prairies. And, though the torrid zone boasts of a strong-limbed and almost steel-shod creature, the ant-bear, his ravages are limited to the destruction of the nests of ants; and, however much this somewhat scarce animal contributes to the result, we must look in another direction for the true tropical analogue of the worm.

The animal we are in search of, and which I venture to think equal to all the necessities of the case, is the termite or white ant. It is a small insect (Fig. 1), with a bloated yellowish-white body and a somewhat large thorax, oblong-shaped, and colored a disagreeable oily brown. The flabby, tallow-like body makes this insect sufficiently repulsive, but it is for quite another reason that the white ant is the worst abused of all living vermin in warm countries. The termite lives almost exclusively upon wood; and, the moment a tree is cut or a log sawed for any economical purpose, this insect is upon its track. One may never see the insect, possibly, in the flesh, for it lives under-ground; but its ravages confront one at every turn. You build your house, perhaps, and for a few months fancy you have pitched upon the one solitary site in the country where there are no white ants. But one day suddenly the door-post totters, and lintel and rafters come down together with a crash. You look at a section of the wrecked timbers and discover that the whole inside is eaten clean away. The apparently solid logs of which the rest of the house is built are now mere cylinders of bark, and through the thickest of them you could push your little finger. Furniture, tables, chairs, chests of drawers, everything made of wood is inevitably attacked, and in a single night a strong trunk is often riddled through and through, and turned into match-wood. There is no limit, in fact, to the depredation by these insects, and they will eat books, or leather, or cloth, or anything, and in many parts of Africa I believe if a man lay down to sleep with a wooden leg it would be a heap of sawdust in the morning. So much feared is this insect now, that no one in certain parts of India and Africa ever attempts to travel with such a thing as a wooden trunk. On the Tanganyika plateau I have camped on ground which was as hard as adamant, and as innocent of white ants apparently as the pavement of St. Paul's, and wakened next morning to find a stout wooden box almost gnawed to pieces. Leather portmanteaus share the same fate, and the only substances which seem to defy the marauders are iron and tin.

FIG. 1.—WORKER WHITE ANT (natural size and magnified).

But what has this to do with earth or with agriculture? The most important point in the work of the white ant remains to be noted. I have already said that the white ant is never seen. Why he should have such a repugnance to being looked at is at first sight a mystery, seeing that he himself is stone-blind. But his coyness is really due to the desire for self-protection, for the moment his juicy body shows itself above-ground there are a dozen enemies waiting to devour it. And yet the white ant can never procure any food until it comes above-ground. Nor will it meet the case for the insect to come to the surface under the shadow of night. Night in the tropics, so far as animal life is concerned, is as the day. It is the great feeding-time, the great fighting-time, the carnival of the carnivores, and of all beasts, birds, and insects of prey from the least to the greatest. It is clear, then, that darkness is no protection to the white ant; and yet without coming out of the ground it can not live. How does it solve the difficulty? It takes the ground out along with it. I have seen white ants working on the top of a high tree, and yet they were underground. They took up some of the ground with them to the tree-top; just as the Esquimaux heap up snow, building it into the low tunnel huts in which they live, so the white ants collect earth, only in this case not

"ALL SORTS OF FANTASTIC SHAPES."

from the surface but from some depth underneath the ground, and plaster it into tunneled ways. Occasionally these run along the ground, but more often mount in endless ramifications to the top of trees, meandering along every branch and twig, and here and there debouching into large covered chambers which occupy half the girth of the trunk. Millions of trees in some districts are thus fantastically plastered over with tubes, galleries, and chambers of earth, and many

pounds weight of subsoil must be brought up for the mining of even a single tree. The building material is conveyed by the insects up a central pipe with which all the galleries communicate, and which at the downward end connects with a series of subterranean passages leading deep into the earth. The method of building the tunnels and covered ways is as follows: At the foot of a tree the tiniest hole cautiously opens in the ground close to the bark. A small head appears with a grain of earth clasped in its jaws. Against the tree trunk this earth-grain is deposited, and the head is withdrawn. Presently it reappears with another grain of earth, this is laid beside the first, rammed tight against it, and again the builder descends underground for more. The third grain is not placed against the tree, but against the former grain; a fourth, a fifth, and a sixth follow, and the plan of the foundation begins to suggest itself as soon as these are in position. The stones or grains, or pellets of earth, are arranged in a semicircular wall, the termite, now assisted by three or four others, standing in the middle between the sheltering wall and the tree and working briskly with head and mandible to strengthen the position. The wall in fact forms a small moon-rampart, and as it grows higher and higher it soon becomes evident that it is going to grow from a low battlement into a long perpendicular tunnel running up the side of the tree. The workers, safely ensconced inside, are now carrying up the structure with great rapidity, disappearing in turn as soon as they have laid their stone and rushing off to bring up another. The way in which the building is done is extremely curious, and one could watch the movements of these wonderful little masons by the hour. Each stone as it is brought to the top is first of all covered with mortar. Of course, without this the whole tunnel would crumble into dust before reaching the height of half an inch; but the termite pours over the stone a moist, sticky secretion, turning the grain round and round with its mandibles until the whole is covered with slime. Then it places the stone with great care upon the top of the wall, works it about vigorously for a moment or two till it is well jammed into its place, and then starts off instantly for another load.

Peering over the growing wall one soon discovers one, two, or more termites of a somewhat larger build, considerably longer, and with a very different arrangement of the parts of the head and especially of the mandibles (Fig. 2). These important-looking individuals saunter about the rampart in the most leisurely way, but yet with a certain air of business as if perhaps the one was the master of the works and the other the architect, but close observation suggests that they are in no wise superintending operations, nor in any immediate way contributing to the structure, for they take not the slightest notice either of the workers or the works. They are posted there, in fact, as sentries, and there

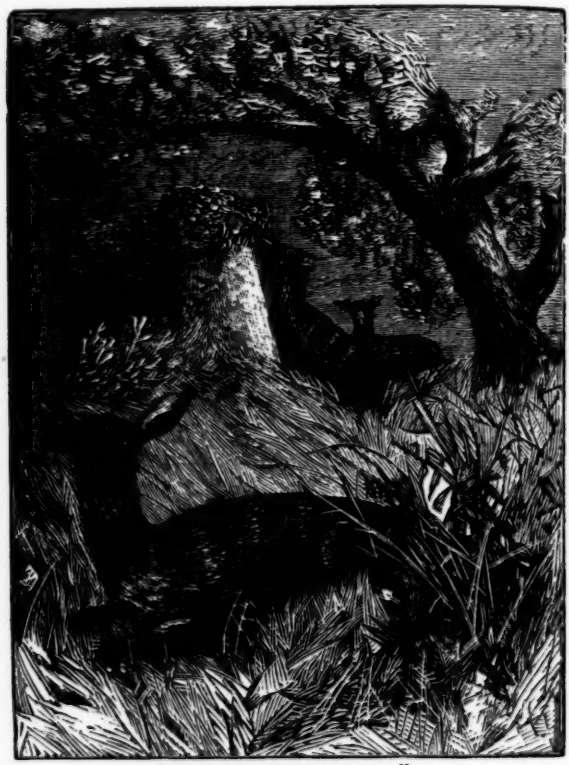
FIG. 2.—SOLDIER WHITE ANT.

they stand, or promenade about, at the mouth of every tunnel, like Sister Ann, to see if anybody is coming. Sometimes somebody does come in the shape of another ant—the real ant this time, not the defenseless *Neuropteron*, but some valiant and belted knight from the warlike *Formicidæ*. Singly or in troops, this rapacious little insect, fearless in its chitinous coat-of-mail, charges down the tree-trunk, its antennæ waving defiance to the enemy and its cruel mandibles thirsting for termite blood. The worker white ant is a poor defenseless creature, and, blind and unarmed, would fall an immediate prey to these well-drilled banditti, who forage about in every tropical forest in unnumbered legion. But at the critical moment, like Goliah from the Philistines, the soldier termite advances to the fight. With a few sweeps of its scythe-like jaws it clears the ground, and, while the attacking party is carrying off its dead, the builders, unconscious of the fray, quietly continue their work. To every hundred workers in a white ant colony, which numbers many thousands of individuals, there are perhaps two of these fighting-men. The division of labor here is very wonderful, and the fact that besides these two specialized forms there are in every nest two other kinds of the same insect, the kings and queens, shows the remarkable height to which civilization in these communities has attained.

But where is this tunnel going to, and what object have the insects in view in ascending this lofty tree? Thirty feet from the ground, across innumerable forks, at the end of a long branch are a few feet of dead wood. How the ants know it is there, how they know its sap has dried up, and that it is now fit for the termites' food, is a mystery. Possibly they do not know, and are only prospecting on the chance. The fact that they sometimes make straight for the decaying limb argues in these instances a kind of definite instinct; but, on the other hand, the fact that in most cases the whole tree, in every branch and limb, is covered with termite-tunnels, would show perhaps that they work most commonly on speculation, while the number of abandoned tunnels, ending on a sound branch in a *cul-de-sac*, proves how often they must suffer the usual disappointments of all such adventurers. The extent to which these insects carry on their tunneling is quite incredible until one has seen it in nature with his own eyes. The tunnels are perhaps about the thickness of a small-sized gas-pipe, but there are junctions here and there of large dimensions, and occasionally patches of earth-work are found embracing nearly the whole trunk for some feet. The outside of these tunnels, which are never quite straight, but wander irregularly along stem and branch, resembles in texture a coarse sand-paper; and the color, although this naturally varies with the soil, is usually a reddish-brown. The quantity of earth and mud plastered over a single tree is often enormous; and when one thinks that it is not only an isolated specimen here and there that is frescoed in this way, but often the whole of the trees of a forest, some

idea will be formed of the magnitude of the operations of these insects and the extent of their influence upon the soil which they are thus ceaselessly transporting from underneath the ground.

In traveling through the great forests of the Rocky Mountains or of the Western States, the broken branches and fallen trunks strewing the ground breast-high with all sorts of decaying litter frequently make locomotion impossible. To attempt to ride through these Western forests, with their mesh-work of interlocked branches and decaying trunks, is often out of the question, and one has to dismount and drag



"USEFUL TO THE SPORTSMAN."

his horse after him as if he were clambering through a wood-yard. But in an African forest not a fallen branch is seen. One is struck at first by a certain clean look about the great forests of the interior, a novel and unaccountable cleanness, as if the forest-bed was carefully swept and dusted daily by unseen elves. And so, indeed, it is. Scavengers of a hundred kinds remove decaying animal matter—from the carcass of the fallen elephant to the broken wing of a gnat—eating it, or carrying it out of sight, and burying it in the deodorizing earth. And these countless millions of termites perform a similar function for the vegetable world, making away with all plants and trees, all stems,

twigs, and tissues, the moment the finger of decay strikes the signal. Constantly in these woods one comes across what appear to be sticks and branches and bundles of fagots, but when closely examined they are seen to be mere casts in mud. From these hollow tubes, which preserve the original form of the branch down to the minutest knot or fork, the ligneous tissue is often entirely removed, while others are met with in all stages of demolition. There is the section (Fig. 3) of an actual specimen which is not yet completely destroyed, and from which the mode of attack may be easily seen. The insects start apparently from two centers. One company attacks the inner bark, which is the favorite morsel, leaving the coarse outer bark untouched, or more usually replacing it with grains of earth atom by atom as they eat it away. The inner bark is gnawed off likewise as they go along, but the woody tissue beneath is allowed to remain to form a protective sheath for the second company who begin work at the center. This second contingent eats its way outward and onward, leaving a thin tube of the outer wood to the last as props to the mine till they have finished the main excavation. When a fallen trunk lying upon the ground is the object of attack, the outer cylinder is frequently left quite intact, and it is only when one tries to drag it off to his campfire that he finds to his disgust that he is dealing with a mere hollow tube a few lines in thickness filled up with mud.

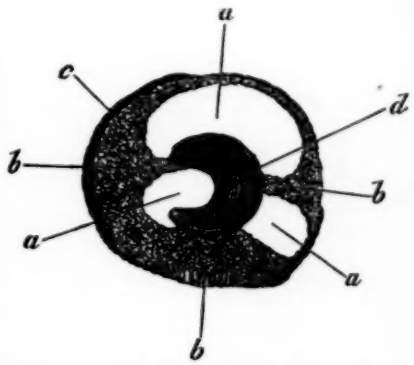


FIG. 3.—*a*, tunnel; *b*, earth; *c*, shreds of outer bark; *d*, remains of branch.

But the works above ground represent only a part of the labors of these slow-moving but most industrious of creatures. The arboreal tubes are only the prolongation of a much more elaborate system of subterranean tunnels (Fig. 4) which extend over large areas and mine the earth sometimes to a depth of many feet or even yards.

The material excavated from these underground galleries and from the succession of domed chambers—used as nurseries and granaries—to which they lead, has to be thrown out upon the surface. And it is from these materials that the huge ant-hills are reared which form so distinctive a feature of the African landscape. These heaps and mounds are so conspicuous that they may be seen for miles, and so numerous are they and so useful as cover to the sportsman, that without them in certain districts hunting would be impossible. The first things, indeed, to strike the traveler in entering the interior are the mounds of the white ant, now dotting the plain in groups like a small cemetery, now rising into mounds singly or in clusters, each

thirty or forty feet in diameter, and ten or fifteen in height, or again standing out against the sky like obelisks, their bare sides carved and fluted into all sorts of fantastic shapes. In India these ant-heaps seldom attain a height of more than a couple of feet, but in Central Africa they form veritable hills, and contain many tons of

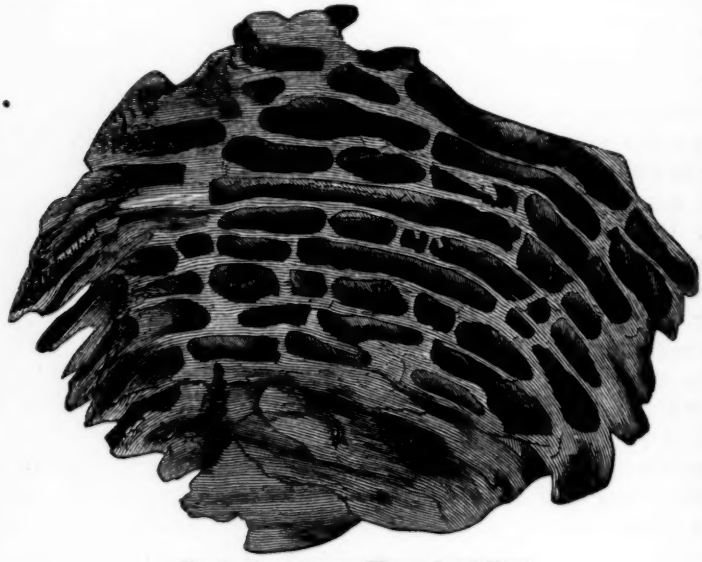


FIG. 4.—GALLERIES IN WHITE ANTS' NEST.

earth. The brick houses of the Scotch mission-station on Lake Nyassa have all been built out of a single ants' nest, and the quarry from which the material has been derived forms a pit beside the settlement some dozen feet in depth. A supply of bricks as large again could probably still be taken from this convenient depot, and the missionaries on Lake Tanganyika and onward to Victoria Nyanza have been similarly indebted to the labors of the termites. In South Africa the Zooloos and Caffres pave all their huts with white-ant earth; and during the Boer war our troops in Praetoria, by scooping out the interior from the smaller beehive-shaped ant-heaps, and covering the top with clay, constantly used them as ovens. These ant-heaps may be said to abound over the whole interior of Africa, and there are three or four distinct varieties. The most peculiar, as well as the most ornate, is a small variety from one to two feet in height, which occurs in myriads along the shores of Lake Tanganyika. It is built in symmetrical tiers, and resembles a pile of small rounded hats, one above another, the rims depending like eaves, and sheltering the body of the hill from rain. To estimate the amount of earth per acre raised from the water-line of the subsoil by white ants would not in some districts be an impossible task, and it would be found probably that the quantity at least

equaled that manipulated annually in temperate regions by the earth-worm.

These mounds, however, are more than mere waste-heaps. Like the corresponding region underground they are built into a mesh-work of tunnels, galleries, and chambers, where the social interests of the community are attended to. The most spacious of these chambers, usually far underground, is very properly allocated to the head of the society, the queen. The queen-termite (Fig. 5) is a very rare insect,

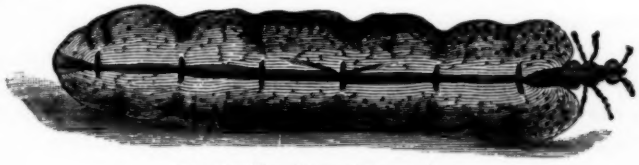


FIG. 5.—THE QUEEN WHITE ANT.

and as there are seldom more than one, or at most two, to a colony, and as the royal apartments are hidden far in the earth, few persons have ever seen a queen, and indeed most, if they did happen to come across it, from its very singular appearance would refuse to believe that it had any connection with white ants. It possesses, indeed, the true termite head (Figs. 6, 7), but there the resemblance to the other members of the family stops, for the size of the head bears about the same proportion to the rest of the body as does the tuft on his Glengarry bonnet to a six-foot Highlander. The phenomenal corpulence of the royal body in the case of the queen-termite is possibly due in part to want of exercise, for once seated upon her throne she never stirs to the end of her days. She lies there, a large, loathsome cylindrical package, two or three inches long, in shape like a sausage, and as

FIG. 6.—HEAD OF QUEEN (magnified).

FIG. 7.—UNDEVELOPED WINGED FEMALE.

FIG. 8.—EGGS.

white as a bolster. Her one duty in life is to lay eggs (Fig. 8), and it must be confessed she discharges her function with complete success, for in a single day her progeny often amounts to many thousands, and for months this enormous fecundity never slackens. The body increases slowly in size, and through the transparent skin the long-folded ovary may be seen, with the eggs, impelled by a peristaltic mo-

tion, passing onward for delivery to the workers who are waiting to carry them to the nurseries where they are hatched. Assiduous attention meantime is paid to the queen by other workers, who feed her diligently, with much self-denial stuffing her with morsel after morsel from their own jaws. A guard of honor in the shape of a few of the larger soldier-ants is also in attendance as a last and almost unnecessary precaution. In addition, finally, to the soldiers, workers, and queen, the royal chamber has also one other inmate—the king. He is a very ordinary-looking insect (Fig. 9), about the same size as the soldiers, but the arrangement of the parts of the head and body is widely different, and like the queen he is furnished with eyes.

FIG. 9.—KING WHITE ANT.

Let me now attempt to show the way in which the work of the termites bears upon the natural agriculture and geology of the tropics. Looking at the question from the large point of view, the general fact to be noted is, that the soil of the tropics is in a state of perpetual motion. Instead of an upper crust, moistened to a paste by the autumn rains, and then baked hard as adamant in the sun, and an under soil, hermetically sealed from the air and light, and inaccessible to all the natural manures derived from the decomposition of organic matters—these two layers being eternally fixed in their relation to one another—we have a slow and continued transference of the layers always taking place. Not only to cover their depredations, but to dispose of the earth excavated from the underground galleries, the termites are constantly transporting the deeper and exhausted soils to the surface. Thus there is, so to speak, a constant circulation of earth in the tropics, a plowing and harrowing, not furrow by furrow and clod by clod, but pellet by pellet and grain by grain.

Some idea of the extent to which the underlying earth of the tropical forests is thus brought to the surface will have been gathered from the facts already described; but no one who has not seen it with his own eyes can appreciate the gigantic magnitude of the process. Occasionally one sees a whole trunk or branch, and sometimes almost an entire tree, so swathed in red mud that the bark is almost completely concealed, the tree looking as if it had been taken out bodily and dipped in some crystallizing solution. It is not only one tree here and there that exhibits the work of the white ant, but in many places the whole forest is so colored with dull-red tunnels and patches as to give a distinct tone to the landscape—an effect which, at a little distance, reminds one of the *abend-roth* in a pine-forest among the Alps. Some regions are naturally more favorable than others to the operations of the termites, and to those who have only seen them at work in India or in the lower districts of Africa this statement may seem an exaggeration. But on one range of forest-clad hills on the great plateau between Lake Nyassa and Tanganyika I have walked for miles through trees, every one of which, without exception, was ramified, more or

less, with tunnels. The elevation of this locality was about five thousand feet above the sea, and the distance from the equator some 9°; but nowhere else have I seen a spot where the termites were so completely masters of the situation as here. If it is the case that in these, the most elevated regions of Central Africa, the termite colonies attain their maximum development, the fact is of much interest in connection with the geological and agricultural function which they seem to serve; for it is here precisely, before the rivers have gathered volume, that alluvium is most wanting; it is here that the tiny head-waters of these same rivers collect the earth for subsequent distribution over the distant plains and coasts; and, though the white ant may itself have no power, in the first instance, of creating soil, as a denuding and transporting agent its ministry can scarcely be exaggerated. If this is its function in the economy of Nature, it is certainly clear that the insect to which this task is assigned is planted where, of all places, it can most effectively fulfill the end.

The direct relation of the termites' work to denudation will still further appear, if we try to imagine the effect upon these accumulations of earth-pellets and grains of an ordinary rainy season. For two or three months in the tropics, though intermittently, the rains lash the forests and soils with a fury such as we, fortunately, have little idea of. And though the earth-works, and especially the larger ant-hills, have marvelous resisting properties, they are not invulnerable, and must ultimately succumb to denuding agents. The tunnels, being only required for a temporary purpose, are made substantial enough only to last the occasion. And, in spite of the natural glue which cements the pellets of earth together, the structure, as a whole, after a little exposure, becomes extremely friable, and crumbles to pieces at a touch. When the earth-tubes crumble into dust in the summer season, the *débris* is scattered over the country by the wind, and in this way tends to increase and refresh the soil. During the rains, again, it is washed into the rivulets and borne away to fertilize with new alluvium the distant valleys or carried downward to the ocean, where along the coast-line it "sows the dust of continents to be." Herodotus, with equal poetic and scientific truth, describes Egypt as "the gift of the Nile." Possibly had he lived to-day he might have carried his vision farther back still, and referred some of it to the labors of the humble termites in the forest slopes about Victoria Nyanza.—*Good Words.*

THE EARLY STUDY OF PLANTS.

By ELIZA A. YOUMANS.

IN the interesting articles, in previous numbers of "The Popular Science Monthly," entitled "An Experiment in Primary Education," by Dr. Mary Putnam-Jacobi, she makes courteous reference to my "First Book of Botany," while dissenting from certain points of its method. The objections, I think, indicate a partial misunderstanding of this method, and, as some of them have been made before and as I have just reissued the plan of study as a volume of "Descriptive Botany," in which the matters criticised remain unchanged, it seems desirable that the erroneous impressions should be corrected. This is the more needful, because of the weight of Mrs. Jacobi's authority in what may be called human science, and because her objections, though briefly stated, come as results of fresh study tested by careful and prolonged experiment. The chief points she makes are contained in the following passage, which is quoted from pages 618 and 619 of the September "Monthly":

"I suppose that most persons seriously interested in education are acquainted with Miss Youmans's admirable little 'First Lessons in Botany,' and the plea she makes for this science as a typical means of training the observing powers of children. According to her plan, the first object studied is the leaf—and the pupil is brought at once, not only to draw the leaf, but to fill out a schedule of description of it. Much may be said in favor of this method, which proceeds from the simple to the complex form, but it is by no means the only possible one; the writing part of the scheme is, moreover, impossible for a child who has not yet learned how to write. There is another method which consists in seizing at once upon the most striking aspect of the subject, and which shall make the most vivid impression upon the imagination. For this purpose the leaf is the least useful, the flower the most. The earliest botanical classifications are based upon the corolla, and, in accordance with a principle already enunciated, a child may often best approach a science through the series of ideas that attended its genesis. The conditions are different for an adult, who requires to get the latest results; the child's mind is always remote from these, but often singularly near to the conceptions entertained by the first observers. Again, it is unnatural to enter upon the beautiful world of plants by the study of forms and outlines—which is much better pursued when abstracted from all other circumstances, as in models of pure mathematical figures. But with plants comes a new idea—that of life, of change, of evolution. It is fitting that this tremendous idea make a profound impression on the child's mind; and this impression may be best secured by watching the

continuous growth of a plant from the seed. The study of life is a study of events, of dynamics, of catastrophes. The earliest observation perceives the extraordinary influence of the surrounding medium upon the destinies of the living organism. It is not difficult to surround these destinies with such a halo of imagination as shall impress on the mind a sense of the mystery, sanctity—I may add, the necessary calamities of life—before it has become absorbed in the consideration of living personalities."

The first statement here made contains an error, which, though apparently trivial, involves a serious misunderstanding of the plan of study adopted in my book. Mrs. Jacobi says that, according to the method, "the first object studied is the leaf, and the pupil is brought at once, not only to draw the leaf," etc. This is a mistake. I have not included drawing as a part of the exercise in the study of leaves, have purposely avoided it, and have always insisted that it is a waste of time and a hindrance to the object I had in view. Instead of facilitating, it impedes the work of observation. The aim is, by the observation of real objects, to form the habit of intelligent discrimination, and such a *habit* can only be formed by numerous and repeated and continued mental exercises, which, with the young beginner, should be as simple and uncomplicated as possible. The method is one of self-instruction, in which the pupil is put upon a *search* to find out things for himself, and he has to inspect a great number of objects to identify, compare, and describe their special characters. Plants were chosen because of the almost endless detail of varying structure which their parts present, and which can only be made familiar by the examination, comparison, and contrast of a great many of them. This forbids the delay entailed by the drawing of specimens, and to insist upon the practice would defeat the method. The pupil could not draw one specimen in a hundred of those with which it is necessary that he should become familiar.

The idea that the parts of plants must be drawn has been the stumbling-block of teachers in using my books from the outset. It is a mode of evading out-of-door work, the collection of multitudes of plants, and their direct and constant observation and comparison. Mere book-science is now condemned, at least nominally, even in the schools; but in place of it we have what is no better, blackboard-science and teacher's talk. My books were made simply for the learner's immediate use as a guide in the direct study of plants, and they have not the slightest value when used in any other way. Yet some teachers have set children to copy their illustrations with chalk upon the blackboard, while others have themselves copied them for their classes, the books being withheld from the pupils. One eminent superintendent of education gravely assured me that my "First Book of Botany" was a book for teachers and not for pupils; and, in exemplification of this idea, I know an instance of a large school for which one hundred

copies were purchased, but in which the contents of the book were doled out by the teacher from the blackboard to a room full of pupils, while ninety-nine copies of the purchased volume remained unopened in the cellar! The most inveterate obstacle to the method is the pervasiveness of the teacher with her drawing, oral instruction, and other school-room processes. They make impossible that training in self-instruction which it was the prime object of the book to secure.

In the plan of the book, leaves were chosen to begin study with, in order to make the first steps easy and effective. Of all the organs of plants, leaves are the simplest and most varied in structure, and are most readily obtained throughout the longest period of the year. With these we are able to begin early the work of self-education, which may be continued along a course of inquiry and discovery that increases in difficulty as by exercise the mind increases in ability. Mrs. Jacobi objects to this. She says, "For the purposes of the beginner the leaf is the least useful, the flower the most." She thinks it better "to seize at once the most striking aspect of the subject, and make the most vivid impression upon the imagination"—adding that "the earliest classifications were based upon the corolla, and a person may often best approach a science through the series of ideas that attended its genesis." Is it the flower or is it only the corolla that Mrs. Jacobi thinks most useful? If the latter, I can only say that, while the corolla is the simplest element of the flower, it is less simple than the leaf, compared with which its forms are few, and not readily classifiable by beginners. If she means the entire flower, we are met by the fact that all its other parts are complex, and often so small as to require the use of a glass in studying their forms. It frequently happens that much strength of judgment is needed in fixing their boundaries and interpreting the appearances they present. Yet, if we are to begin with the flower, it is this complex portion of the plant that Mrs. Jacobi would offer first for the uncultivated attention of the child. The flower was early used in artificial classification, and it is true that the education of the individual must have a general correspondence with the evolution of the race, but this principle can have only a very partial application in primary education, and in this instance its application violates an important law of mental development. It is a fundamental principle of mental growth that the relatively simple and easy shall come before and lead on to the relatively complex and difficult, and to contravene this law is certainly bad education. Nor can I see how the showiness of flowers can in any degree compensate for this total inversion of mental processes. The sensuous interest in flowers is trivial in comparison with the deeper intellectual interest of the child, when discovering for himself the features of plants, and the resemblances of various parts by which relations and affinities are determined. I have found in a long experience with children that the

curiosity, the pleasure, and even the excitement that come from a connected course of observations upon simple leaves are all-sufficient as a stimulus to continued effort, and the concurrent testimony of able teachers who have practiced the method abundantly justifies my own results.

This objection, that I begin with leaves in the study of plants, has been often made before. Of course, there may be various points of approach to the subject; but I had to adopt one, and I chose that which is unquestionably most favorable for beginning the work of self-instruction. None of the objections that I have seen have any force against the proved advantage of the plan pursued.

In further criticism of the method Mrs. Jacobi says, "Again, it is unnatural to enter upon the beautiful world of plants by the study of forms and outlines—which is much better pursued when abstracted from all other circumstances, as in models of pure mathematical figures." I am at a loss to understand this. Does Mrs. Jacobi regard me as attempting to teach geometry by the forms and outlines of leaves? I certainly have made no other use of forms and outlines than results from the inevitable relations of the mind to its environment. Forms and outlines are properties by which objects are known. The properties of bodies revealed to us through sensation are used by the child in the study of plants in exactly the same way that they are earlier used in the study of household and all familiar objects. The only difference is that, in descriptive botany, these observations are made with more precision, have a logical unity, and a conscious purpose. I am the more puzzled to understand in what the unnaturalness of the study of forms and outlines of leaves consists, because Mrs. Jacobi tells us (p. 472) that, "before the child has a clearly intellectual life on any other subjects, it attains a very definite power to distinguish the square, the oval, the spiral." If this be true, how can the study of forms of any objects be considered unnatural? If, as she relates, a child may describe bits of cake as squares and cubes, "make pentagons and octagons with knife and fork," characterize onions as "oblates," without being unnatural, why does she become so when she describes leaves as round, oval, oblong, etc., as the case may be?

But perhaps Mrs. Jacobi means that "it is unnatural to enter upon the beautiful world of plants by the study of forms and outlines," because the most beautiful and attractive parts should receive attention first. This might accord with the dictates of æsthetic feeling, but there is no reason why it should be regarded as especially the *natural* way. The truth is, this point has been settled by the history of botanical method. The flower, the most conspicuous and beautiful part, was for a long time taken alone as the basis of a classification which depended upon the number and mode of arrangement of its essential organs, to the neglect of the remaining plant-characters; but that is now recog-

nized as the *artificial* system. Afterward the flower was deposed from its supremacy, and all the characters of plants, of which forms and outlines are leading ones, were taken into account in grouping them, and this is named the *natural* system. I should rather say that to make a fanciful idea predominant in a method of study is unnatural, while the truly natural method is that which conforms to the requirements of the mind and the progress of the science to be studied, and which will therefore lead to the best acquaintance with the truth of nature.

Again, after objecting to the early study of plants in their most simplified forms by children, Mrs. Jacobi says: "But with plants comes a new idea—that of life, of change, of evolution. It is fitting that these tremendous ideas make a profound impression on the child's mind; and this impression may be best secured by watching the continuous growth of a plant from the seed." I confess to having read this passage with no little surprise. It may be well at times to strike out from the beaten track, and take independent views, but some things are, nevertheless, established. Mrs. Jacobi here ignores the latest progress in the methods of botanical study for minds of all grades. The plan of beginning the study of the vegetable kingdom by inquiries concerning life-processes is now discredited and abandoned by the best botanical authors and teachers. It is the old method of studying physiological botany before descriptive botany, or the inner mysteries of plant organization before the external characters and relations of plant-structures by which they are known and classified. In his botanical text-book, published more than forty years ago, Professor Gray began with the idea of life and growth, but, in the series of botanical text-books he is now preparing, the first volume is devoted to the study of the external aspects of plants. He recognizes that this should come first, saying, "It will furnish the needful preparation to those who proceed to the study of vegetable physiology and anatomy." The reasons for adopting this order are conclusive, but they are strongest in the case of beginners; and yet Mrs. Jacobi adopts the old plan condemned by experience, in the case of a child five years old. If there is any truth in mental science, or any value in the experience of practical teachers, there is in childhood a special intellectual fitness for acquiring a knowledge of the external characters of organisms, and an unfitness for grasping and comprehending the obscure and difficult operations of life as manifested by these organisms. Nor can the reason which Mrs. Jacobi offers for the course taken be for a moment accepted as sound. She would introduce a little child to the study of plants through the grand gateway of evolution, to impress it at the start with the tremendous conception of unfolding life. It is proper, and I have recommended it in my little book for beginners, to make the germination of seeds an experimental

exercise in observation ; and this is as far as the juvenile capacity can go. It is neither fitting nor possible that tremendous ideas should make a profound impression upon a child's mind. It has no capability either to appreciate or to receive them. Savages are incapable of wonder; they do not know enough to wonder. Said Professor Grove, in his address before the British Association at Nottingham, "If the primitive inhabitants of Britain could emerge and behold the wonderful triumphs of art and science in our civilization, it is doubtful if they would know enough to be astonished." And so with children. We may teach them to say of the stars, "How I wonder what you are!" but they do not *wonder* in the least. Only minds highly cultivated and widely informed are capable of appreciating the tremendous idea of evolution so as to be deeply impressed by it. We are not to suppose, because the young readily acquire terms and phrases, and seem in a way to understand them, that they are therefore in possession of their real and full meanings. There are stages in the process of assimilating ideas which the pupil reaches one after another in the slow course of mental unfolding. Before the period of its formal education, in the natural development of mind, the child never leaps forward into the complex and difficult, but insensibly grows into greater and greater strength through its spontaneous interest in simple things. This is the safest course to follow, because we are here on the solid ground of Nature's own method.

ON THE SOLAR CORONA.*

By WILLIAM HUGGINS, F. R. S.

IF it were usual to prefix a motto to these evening discourses, I might have selected such words as "Seeing the Invisible," for I have to describe a method of investigation by which what is usually unseeable may become revealed. We live at the bottom of a deep ocean of air, and therefore every object outside the earth can be seen by us only as it looks when viewed through this great depth of air. Professor Langley has shown recently that the air mars, colors, distorts, and therefore misleads and cheats us to an extent much greater than was supposed. Langley considers that the light and heat absorbed and scattered by the air and the particles of matter floating in it amount to no less than forty per cent of the light falling upon it. In consequence of this want of transparency and of the presence of finely divided matter always more or less suspended in it, the air, when the sun shines upon it, becomes itself a source of light. This illuminated

* A lecture delivered at the Royal Institution of Great Britain, Friday evening, February 20, 1885.

aërial ocean necessarily conceals from us by overpowering them any sources of light less brilliant than itself which are in the heavens beyond. From this cause the stars are invisible at midday. This illuminated air also conceals from us certain surroundings and appendages of the sun, which become visible on the very rare occasions when the moon coming between us and the sun cuts off the sun's light from the air where the eclipse is total, and so allows the observer to see the surroundings of the sun through the cone of unilluminated air which is in shadow. It is only when the aërial curtain of light is thus withdrawn that we can become spectators of what is taking place on the stage beyond. The magnificent scene never lasts more than a few minutes, for the moon passes and the curtain of light is again before us. On an average, once in two years this curtain of light is lifted for from three to six minutes. I need not say how difficult it is from these glimpses at long intervals even to guess at the plot of the drama which is being played out about the sun.

The purpose of this discourse is to describe a method by which it is possible to overcome the barrier presented to our view by the bright screen of air, and so watch from day to day the changing scenes taking place behind it in the sun's surroundings.

The object of our quest is to be found in the glory of radiant beams and bright streamers intersected by darker rifts which appears about the sun at a total solar eclipse. The corona possesses a structure of great complexity, which is the more puzzling in its intricate arrangement because, though we seem to have a flat surface before us, it exists really in three dimensions. If we were dwellers in Flatland and the corona were a sort of glorified catherine-wheel, the task of interpretation would seem less difficult. But, as we are looking at an object having thickness as well as extension, the forms seen in the corona must appear to us more or less modified by the effect of perspective. This consideration tells us also that the intrinsic brightness of the corona toward the sun's limb is much less than its apparent brightness as seen by us, of which no inconsiderable part must be due to the greater extent of corona in the line of sight as the sun is approached. The corona undergoes great and probably continual change, as the same coronal forms are not present at different eclipses.

The attempts which have been made from time to time to see the corona without an eclipse have been based mainly upon the hope that if the eye were protected from the intense direct light of the sun, and from all light other than that from the sky immediately about the sun, then the eye might become sufficiently sensitive to perceive the corona. These attempts have failed because it was not possible to place the artificial screen where the moon comes, outside our atmosphere, and so keep in shadow the part of the air through which the observer looks. The latest attempts have been made by Professor Langley at Mount Whitney, and Dr. Copeland, assistant to Lord

Crawford, on the Andes. Professor Langley says, "I have tried visual methods under the most favorable circumstances, but with entire non-success." Dr. Copeland observed at Puno, at a height of 12,040 feet. He says, "It ought to be mentioned that the appearances produced by the illuminated atmosphere were often of the most tantalizing description, giving again and again the impression that my efforts were about to be crowned with success."

There are occasions on which the existence of the brighter part of the corona near the sun's limb can be detected without an eclipse. The brightness of the sky near the sun's limb is due to two distinct factors, the air-glare and the corona behind it, which M. Janssen considers to be brighter than the full moon. When Venus comes between us and the sun, it is obvious that the planet, as it approaches the sun, comes in before the corona, and shuts off the light which is due to it. To the observer the sky at the place where the planet is appears darker than the adjoining parts, that is to say, the withdrawal of the coronal light from behind has made a sensible diminution in the brightness of the sky. It follows that the part of the sky behind which the corona is situated must be brighter in a small degree than the adjoining parts, and it would perhaps not be too much to say that the corona would always be visible when the sky is clear, if our eyes were more sensitive to small differences of illumination of adjacent areas. My friend Mr. John Brett, A. R. A., tells me that he is able to see the corona in a telescope of low power.

The spectroscopic method by which the prominences can be seen fails because a part only of the coronal light is resolved by the prism into bright lines, and of these lines no one is sufficiently bright and co-extensive with the corona to enable us to see the corona by its light, as the prominences may be seen by the red, the blue, or the green line of hydrogen.

The corona sends to us light of three kinds: 1. Light which the prism resolves into bright lines, which has been emitted by luminous gas. 2. Light which gives a continuous spectrum, which has come from incandescent liquid or solid matter. 3. Reflected sunlight, which M. Janssen considers to form the fundamental part of the coronal light.

The problem to be solved was how to disentangle the coronal light from the air-glare mixed up with it, or in other words how to give such an advantage to the coronal light that it might hold its own sufficiently for our eyes to distinguish the corona from the bright sky.

When the report reached this country in the summer of 1882 that photographs of the spectrum of the corona taken during the eclipse in Egypt showed that the coronal light seen from the earth as a whole is strong in the violet region, it seemed to me probable that if by some method of selective absorption this kind of light were isolated, then when viewed by this kind of light alone the corona might be at a sufficient advantage relatively to the air-glare to become visible. Though

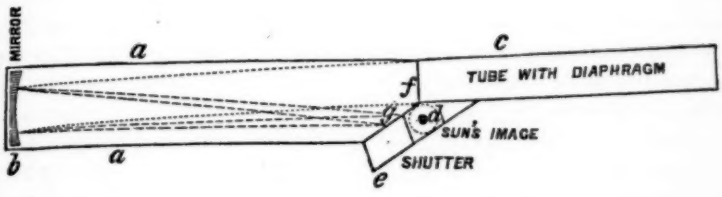
this light falls within the range of vision, the eye is less sensitive to small differences of illumination near this limit of its power. This consideration and some others led me to look to photography for aid, for it is possible by certain technical methods to accentuate the extreme sensitiveness of a photographic plate for minute differences of illumination. [A cardboard, on which a corona had been painted by so thin a wash of Chinese white that it was invisible to the audience, had been photographed. The photograph thrown upon the screen showed the corona plainly.] This cardboard represents the state of things in the sky about the sun. The painted corona is brighter than the cardboard, but our eyes are too dull to see it. In like manner the part of the sky near the sun where there is a background of corona is brighter than the adjoining parts where there is no corona behind, but not in a degree sufficiently great for our eyes to detect the difference.

A photographic plate possesses another and enormous advantage over the eye, in that it is able to furnish a permanent record of the most complex forms from an instantaneous exposure.

In my earlier experiments the necessary isolation of violet light was obtained by interposing a screen of colored glass or a cell containing potassic permanganate. The possible coming of false light upon the sensitive plate from the glass sides of the cell, as well as from precipitation due to the decomposition of the potassic permanganate under the sun's light, led me to seek to obtain the necessary light-selection in the film itself. Captain Abney had shown that argentic bromide, iodide, and chloride, differ greatly in the kind of light to which they are most sensitive. The chloride is most strongly affected by violet light from *h* to a little beyond K. It was found possible by making use of this selective action of argentic chloride to do away with an absorptive medium. To prevent reflected light, the back of the plate was covered with asphaltum varnish, and frequently a small metal disk a little larger than the sun's image was interposed in front of the plate to cut off the sun's direct light.

The next consideration was as to the optical means by which an image of the sun, as free as possible from imperfections of any kind, could be formed upon the plate. For several obvious reasons the use of lenses was given up, and I turned to reflection from a mirror of speculum metal. My first experiments were made with a Newtonian telescope by Short. With this instrument, during the summer of 1882, about twenty plates were taken on different days, in all of which coronal forms are to be seen about the sun's image. After a very critical examination of these plates, in which I was greatly helped by the kind assistance of Professor Stokes and Captain Abney, there seemed to be good ground to hope that the corona had really been obtained on the plates. [One of these negatives, obtained in August, 1882, was shown upon the screen.]

In the spring of the following year, 1883, the attack upon the corona was carried on with a more suitable apparatus. The Misses Lassell were kind enough to lend me a seven-foot Newtonian telescope made by Mr. Lassell, which possesses great perfection of figure and retains still its fine polish. For the purpose of avoiding the disadvantage of a second reflection from the small mirror, and also of reducing the aperture to three and a half inches, which gives a more manageable amount of light, I adopted the arrangement of the instrument which is shown in the following woodcut:



The speculum *b* remains in its place at the end of the tube *a*, *a*, by which the mechanical inconvenience of tilting the speculum within the tube as in the ordinary form of the Herschelian telescope is avoided.

The small plane speculum and the arm carrying it were removed. The open end of the tube is fitted with a mahogany cover. In this cover at one side is a circular hole, *f*, three and a quarter inches diameter, for the light to enter; below is a similar hole over which is fitted a framework to receive the "backs" containing the photographic plates, and also to receive a frame with fine-ground glass for putting the apparatus into position. Immediately below, toward the speculum, is fixed a shutter with an opening of adjustable width, which can be made to pass across more or less rapidly by the use of India-rubber bands of different degrees of strength. In front of the opening *f* is fixed a tube, *e*, six feet long, fitted with diaphragms, to restrict as far as possible the light which enters the telescope to that which comes from the sun and the sky immediately around it. The telescope-tube *a*, *a*, is also fitted with diaphragms, which are not shown in the diagram, to keep from the plate all light, except that coming directly from the speculum. It is obvious that, when the sun's light entering the tube at *f* falls upon the central part of the speculum, the image of the sun will be formed in the middle of the second opening at *d*, about two inches from the position it would take if the tube were directed axially to the sun. The exquisite definition of the photographic images of the sun shows, as was to be expected, that this small deviation from the axial direction, two inches in seven feet, does not affect sensibly the performance of the mirror. The whole apparatus is firmly strapped on to the refractor of the equatorial in my observatory, and carried with it by the clock-motion.

The performance of the apparatus is very satisfactory. The photographs show the sun's image sharply defined; even small spots are seen. When the sky is free from clouds, but presents a whity appearance from the large amount of scattered light, the sun's image is well defined upon a uniform background of illuminated sky, without any sudden increase of illumination immediately about it. It is only when the sky becomes clear and blue in color that coronal appearances present themselves with more or less distinctness. [Several negatives taken during the summer of 1883 were shown on the screen.] In our climate the increased illumination of the sky where there is a background of coronal light is too small to permit the photographs which show this difference to be otherwise than very faint. A small increase of exposure, or of development, causes it to be lost in the strong photographic action of the air-glare. For this reason, the negatives should be examined under carefully arranged illumination. They are not, therefore, well adapted for projection on a screen. [A negative taken with a whity sky showed a well-defined image of the sun, with a sensibly uniform surrounding of air-glare, but without any indication of the corona. In the case of the other negatives exhibited, which were taken on clearer days, an appearance, very coronal in character, was to be seen about the sun.]

On May 6th the corona was photographed during a total eclipse at Caroline Island by Messrs. Lawrence and Woods. This circumstance furnished a good opportunity of subjecting the new method to a crucial test, namely, by making it possible to compare the photographs taken in England, where there was no eclipse, with those taken at Caroline Island of the undoubtedly true corona during the eclipse. On the day of the eclipse the weather was bad in this country, but plates were taken before the eclipse, and others taken later on. These plates were placed in the hands of Mr. Wesley, who had had great experience in making drawings from the photographs taken during former eclipses. Mr. Wesley drew from the plates before he had any information of the results obtained at Caroline Island, and he was therefore wholly without bias in the drawings which he made from them. [Photographs of Mr. Wesley's drawings were projected on the screen, and then a copy of the Caroline Island eclipse photograph. The general resemblance was unmistakable, but the identity of the object photographed in England and at Caroline Island was placed beyond doubt by a remarkably formed rift on the east of the north pole of the sun. This rift, slightly modified in form, was to be seen in a plate taken about a solar rotation period before the eclipse, and also on a plate taken about the same time after the eclipse. The general permanence of this great rift certainly extended over some months, but no information is given as to whether the corona rotates with the sun. For from the times at which the plates were taken, one about a rotation period before and the other a rotation period after the eclipse,

it is obvious the rift might have gone round with the sun, but there is no positive evidence on this point.*]

As the comparison of the English plates with those taken at Caroline Island possesses great interest, I think it well to put on record here a letter written by Mr. Lawrence to Professor Stokes, dated Sept. 14, 1883 :

"Dr. Huggins called upon Mr. Woods this morning and showed us the drawings Mr. Wesley has made of his coronas. He told us that he particularly did not wish to see our negatives, but that he would like us to compare his results with ours. We did so, and found that some of the strongly marked details could be made out on his drawings, a rift near the north pole being especially noticeable ; this was in a photograph taken on April 3d, in which the detail of the northern hemisphere is best shown, while the detail of our southern hemisphere most resembles the photograph taken on June 6th ; in fact, our negatives seem to hold an intermediate position. Afterward I went with Dr. Huggins and Mr. Woods to Burlington House to see the negatives. The outline and distribution of light in the inner corona of April 3d are very similar to those on our plate which had the shortest exposure ; the outer corona is, however, I think, hidden by atmospheric glare. As a result of the comparison, I should say that Dr. Huggins's coronas are certainly genuine as far as 8′ from the limb."

Though the plates which were obtained during the summer of 1883 appeared to be satisfactory to the extent of showing that there could be little doubt remaining but that the corona had been photographed without an eclipse, and therefore of justifying the hope that a successful method for the continuous investigation of the corona had been placed in the hands of astronomers, yet, as the photographs were taken under the specially unfavorable conditions of our climate, they failed to show the details of the structure of the corona.

The next step was obviously to have the method carried out at some place of high elevation, where the large part of the glare which is due to the lower and denser parts of our atmosphere would no longer be present. I ventured to suggest to the Council of the Royal Society that a grant from the fund placed annually by the Government at the disposal of the Royal Society should be put in the hands of a small committee for this purpose. This suggestion was well received, and a committee was appointed by the Council of the Royal Society. The committee selected the Riffel, near Zermatt in Switzerland, a station which has an elevation of 8,500 feet, and the further advantages of easy access, and of hotel accommodation. The committee was fortunate in securing the services, as photographer, of Mr. Ray Woods, who as assistant to Professor Schuster had photographed the corona during the eclipse of 1882 in Egypt, and who in 1883, in conjunction with Mr. Lawrence, had photographed the eclipse of that year at Caroline Island.

* See Plates XI and XIa, "British Association Report," 1883, p. 348.

Mr. Woods arrived at the Riffel in the beginning of July, 1884, with an apparatus, similar to one shown in the woodcut on a former page, constructed by Mr. Grubb.

Captain Abney, who had made observations on the Riffel in former years, had remarked on the splendid blue-black skies which were seen there whenever the lower air was free from clouds or fog. But unfortunately during the last year or so a veil of finely divided matter of some sort has been put about the earth, of which we have heard so much in the accounts from all parts of the earth of gorgeous sunsets and after-glows. This fine matter was so persistently present in the higher regions of the atmosphere during last summer, that Mr. Woods did not get once a really clear sky. On the contrary, whenever visible cloud was absent, then instead of a blue-black sky there came into view a luminous haze, forming a great aureole about the sun, of a faint red color, which passed into bluish white near the sun. Mr. Woods found the diameter of the aureole to measure about 44°. This appearance about the sun has been seen all over the world during last summer, but with greatest distinctness at places of high elevation.

The relative position of the colors, blue inside and red outside, shows that the aureole is a diffraction phenomenon due to minute particles of matter of some kind. Mr. Ellery, Captain Abney, and some others, consider the matter to be water in the form probably of minute ice-spicules; others consider it to consist of particles of volcanic dust projected into the air during the eruption at Krakatoa; but whatever it is, and whencesoever it came, it is most certainly matter in the wrong place so far as astronomical observations are concerned, and in a peculiar degree for success in photographing the corona. We are only beginning to learn that, whether in our persons or in our works, it is by minimized matter chiefly that we are undone. So injurious was the effect of this aureole that it was not possible to obtain any photographs of the corona at my observatory near London. This great diffraction aureole went far to defeat the object for which Mr. Woods had gone to the Riffel, but fortunately the great advantage of being free from the effects of the lower eight thousand feet of denser air told so strongly that, notwithstanding the ever-present aureole, Mr. Woods was able to obtain a number of plates on which the corona shows itself with more or less distinctness. [Three untouched photographic copies of the plates taken at the Riffel were shown upon the screen.] From the presence of the aureole the negatives show less detail than we have every reason to believe would have been the case if the sky had been as blue and clear as in some former years. This circumstance makes great care necessary in the discussion of these plates, and it would be premature to say what information is to be obtained from them.

[As an illustration of the differences of form which the corona has assumed at different eclipses, photographs taken in 1871, 1878, 1882,

and 1883 were projected on the screen. Attention was called to the equatorial extension seen in the photograph taken in 1878, and to the suggestion which had been put forward that this peculiar character was connected with the then comparative state of inactivity of the sun's surface, at a period of minimum sun-spot action, especially as an equatorial extension was observed in 1867.]

It is now time that something should be said of the probable nature of the corona.

Six hypotheses have been suggested:

1. That the corona consists of a gaseous atmosphere resting upon the sun's surface and carried round with it.

2. That the corona is made up, wholly or in part, of gaseous and finely divided matter which has been ejected from the sun, and is in motion about the sun from the forces of ejection, of the sun's rotation, and of gravity—and possibly of a repulsion of some kind.

3. That the corona resembles the rings of Saturn, and consists of swarms of meteoric particles revolving with sufficient velocity to prevent their falling into the sun.

4. That the corona is the appearance presented to us by the unceasing falling into the sun of meteoric matter and the *débris* of comets' tails.

5. That the coronal rays and streamers are, at least in part, meteoric streams strongly illuminated by their near approach to the sun, neither revolving about nor falling into the sun, but permanent in position and varying only in richness of meteoric matter, which are parts of eccentric comet orbits. This view has been supported by Mr. Proctor, on the ground that there must be such streams crowding richly together in the sun's neighborhood.

6. The view of the corona suggested by Sir William Siemens in his solar theory.

It has been suggested, even, that the corona is so complex a phenomenon that there may be an element of truth in every one of these hypotheses. Anyway, this enumeration of hypotheses, more or less mutually destructive, shows how great is the difficulty of explaining the appearances which present themselves at a total solar eclipse, and how little we really know about the corona.

An American philosopher, Professor Hastings, has revived a prior and altogether revolutionary question: Has the corona an objective existence? Is it anything more than an optical appearance depending upon diffraction? Professor Hastings has based his revival of this long-discarded negative theory upon the behavior of a coronal line which he saw, in his spectroscope, change in length east and west of the sun during the progress of the eclipse at Caroline Island. His view appears to rest on the negative foundation that Fresnel's theory of diffraction may not apply in the case of a total eclipse, and that at such great distances there is a possibility that the interior of the

shadow might not be entirely dark, and so to an observer might cause the appearance of a bright fringe around the moon.*

Not to speak of the recent evidence of the reality of the corona from the photographs which have been taken when there is no intervening moon to produce diffraction, there is the adverse evidence afforded by the peculiar spectra of different parts of the corona, and by the complicated and distinctly peculiar structure seen in the photographs taken at eclipses. The crucial test of this theory appears to be that, if it be true, then the corona would be much wider on the side where the sun's limb is least deeply covered, that is to say, the corona would alter in width on the two sides during the progress of the eclipse. Not to refer to former eclipses where photographs taken at different times and even at different places have been found to agree, the photographs taken during the eclipse at Caroline Island show no such changes. M. Janssen says, "Les formes de la couronne ont été absolument fixes pendant toute la durée de la totalité." The photographs taken by Messrs. Lawrence and Woods also go to show that the corona suffered no such alterations in width or form as would be required by Professor Hastings's theory during the passage of the moon.

We have, therefore, I venture to think, a right to believe in an objective reality of some sort about the sun corresponding to the appearance which the corona presents to us. At the same time some very small part of what we see must be due to a scattering of the coronal light itself by our air, but the amount of this scattered light over the corona must be less than what is seen over the dark moon.

That the sun is surrounded by a true gaseous atmosphere of relatively limited extent there can be little doubt, but many considerations forbid us to think of an atmosphere which rises to a height which can afford any explanation of the corona, which streams several hundred thousand miles above the photosphere. For example, a gas at that height, if hundreds or even thousands of times lighter than hydrogen, would have more than metallic density near the sun's surface—a state of things which spectroscopic and other observations show is not the case. The corona does not exhibit the rapid condensation toward the sun's limb which such an atmosphere would present, especially when we take into account the effect of perspective in increasing the apparent brightness of the lower regions of the corona. There is, too, the circumstance that comets have passed through the upper part of the corona without being burned up or even sensibly losing velocity.

There can scarcely be doubt that matter is present about the sun wherever the corona extends, and further that this matter is in the form of a fog. But there are fogs and fogs. The air we breathe,

* Report of the Eclipse Expedition to Caroline Island, May, 1883. Memoir of the National Academy of Sciences, Washington.

when apparently pure, stands revealed as a dense swarming of millions of motes if a sunbeam passes through it. Even such a fog is out of the question. If we conceive of a fog so attenuated that there is only one minute liquid or solid particle in every cubic mile, we should still have matter enough, in all probability, to form a corona. That the coronal matter is of the nature of a fog is shown by the three kinds of light which the corona sends to us—reflected solar light scattered by particles of matter, solid or liquid; and, secondly, light giving a continuous spectrum, which tells us that these solid or liquid particles are incandescent; while the third form of spectrum of bright lines, fainter and varying greatly at different parts of the corona and at different eclipses, shows the presence also of light-emitting gas. This gas existing between the particles need not necessarily form a true solar atmosphere, which the considerations already mentioned make an almost impossible supposition, for we may well regard this thin gas as carried up with the particles, or even to some extent to be furnished by them under the sun's heat.

It will be better to consider first the probable origin of this coronal matter, and by what means it can find itself at such enormous heights above the sun.

There is another celestial phenomenon, very unlike the corona at first sight, which may furnish us possibly with some clew to its true nature. The head of a large comet presents us with luminous streamers and rifts and curved rays, which are not so very unlike, on a small scale, some of the appearances which are peculiarly characteristic of the corona.* We do not know for certain the conditions under which these cometary appearances take place, but the hypothesis which seems on the way to become generally accepted attributes them to electrical disturbances, and especially to a repulsive force acting from the sun, possibly electrical, which varies as the surface, and not, like gravity, as the mass. A force of this nature in the case of highly attenuated matter can easily master the force of gravity, and, as we see in the tails of comets, blow away this thin kind of matter to enormous distances in the very teeth of gravity.

If such a force of repulsion is experienced in comets, it may well be that it is also present in the sun's surroundings. If this force be electrical, it can only come into play when the sun and the matter subjected to it have electric potentials of the same kind, otherwise the attraction on one side of a particle would equal the repulsion on the other. On this theory the coronal matter and the sun's surface must both be in the same electrical state, the repelled matter negative if the sun is negative, positive if the sun is positive.

The grandest terrestrial displays of electrical disturbance, as seen in lightning and the aurora, must be of a small order of magnitude as compared with the electrical changes taking place in connection

* See "Comets," Royal Institution Proceedings, vol. x, p. 1.

with the ceaseless and fearful activity of the sun's surface; but we do not know how far these actions, or the majority of them, may be in the same electrical direction, or what other conditions there may be, so as to cause the sun's surface to maintain a high electrical state, whether positive or negative. A permanence of electric potential of the same kind would seem to be required by the phenomena of comets' tails.

If such a state of high electric potential at the photosphere be granted as is required to give rise to the repulsive force which the phenomena of comets appear to indicate, then, considering the gaseous irruptions and fiery storms of more than Titanic proportions which are going on without ceasing at the solar surface, it does not go beyond what might well be, to suppose that portions of matter ejected to great heights above the photosphere, and often with velocities not far removed from that which would be necessary to set it free from the sun's attraction, and very probably in the same electric state as the photosphere, might so come under this assumed electric repulsion as to be blown upward and to take on forms such as those seen in the corona: the greatest distances to which the coronal streamers have been traced are small as compared with the extent of the tails of comets, but then the force of gravity which the electrical repulsion would have to overcome near the sun would be enormously greater.

It is in harmony with this view of things that the positions of greatest coronal extension usually correspond with the spot-zones where the solar activity is most fervent; and also that a careful examination of the structure of the corona suggests strongly that the forces to which this complex and varying structure is due have their seat in the sun. Matter repelled upward would rise with the smaller rotational velocity of the photosphere, and lagging behind would give rise to curved forms; besides, the forces of irruption and subsequent electrical repulsion might well vary in direction and not be always strictly radial, and under such circumstances a structure of the character which the corona presents might well result. The sub-permanency of any great characteristic coronal forms, as, for example, the great rift seen in the photographs of the Caroline Island eclipse, and also in those taken in England a month before the eclipse and about a month afterward, must probably be explained by the maintenance for some time of the conditions upon which the forms depend, and not by an unaltered identity of the coronal matter; the permanency belonging to the form only, and not to the matter, as in the case of a cloud over a mountain-top or of a flame over the mouth of a volcano. If the forces to which the corona is due have their seat in the sun, the corona would probably rotate with it; but if the corona is produced by conditions external to the sun, then the corona might not be carried round with the sun.

We have seen that the corona consists probably of a sort of incan-

descent fog, which at the same time scatters to us the photospheric light. Now, we must bear in mind the very different behavior of a gas, and of liquid or solid particles in the near neighborhood of the sun. A gas need not be greatly heated, even when near the sun, by the radiated energy. Heated gas from the photosphere would rapidly lose heat; but, on the other hand, liquid or solid particles, whether originally carried up as such or subsequently formed by condensation, would absorb the sun's heat, and at coronal distances would soon rise to a temperature not very greatly inferior to that of the photosphere. The gas which the spectroscope shows to exist along with the incandescent particles of the coronal stuff may therefore have been carried up as gas or have been in part distilled from the coronal particles under the enormous radiation to which they are exposed. Such a view would not be out of harmony with the very different heights to which different bright lines may be traced at different parts of the corona and at different eclipses. For obvious reasons, gases of different vapor density would be differently acted upon by a repulsive force which varies as the surface, and would to some extent be winnowed from each other; the lighter the gas the more completely would it come under the sway of repulsion, and so would be carried to a greater height than the gas more strongly held down by gravity. The relative proportions, at different heights of the corona, of the gases which the spectroscope shows to exist there (and recently Captain Abney and Professor Schuster have shown that in addition to the bright lines already known the spectrum of the corona of 1882 gave the rhythmical group of the ultra-violet lines of hydrogen which are characteristic of the photographic spectra of the white stars, and some other lines also) would vary from time to time, and depend in part upon the varying state of activity of the photosphere, and so probably establish a connection with the spectra of the prominences. This view of the corona would bring it within the charmed circle of interaction which seems to obtain among the phenomena of sun-spots and terrestrial magnetic disturbances and auroræ.

Many questions remain unconsidered; among others, whether the light emitted by the gaseous part of the corona is due directly to the sun's heat, or to electrical discharges taking place in it of the nature of the aurora. Further, what becomes of the coronal matter on the theory which has been suggested? Is it permanently carried away from the sun, as the matter of the tails of comets is lost to them? Among other considerations it may be mentioned that electric repulsion can maintain its sway only so long as the repelled particle remains in the same electrical state: if through electric discharges it ceases to maintain the electrical potential it possessed, the repulsion has no more power over it, and gravity will be no longer mastered. If, when this takes place, the particle is not moving away with a velocity sufficiently great to carry it from the sun, the particle will return to the sun.

Of course, if the effect of any electric discharges or other conditions has been to change the potential of the particle from positive to negative, or the reverse, as the case may be, then the repulsion would be changed into an attraction acting in the same direction as gravity. In Mr. Wesley's drawings of the corona, especially in those of the eclipse of 1871, the longer rays or streamers appear not to end, but to be lost in increasing faintness and diffusion, but certain of the shorter rays are seen to turn round and to descend to the sun.*

It is difficult for us living in dense air to conceive of the state of attenuation probably present in the outer parts of the corona. Mr. Johnstone Stoney has calculated that more than twenty figures are needed to express the number of molecules in a cubic centimetre of ordinary air; and Mr. Crookes shows us in his tubes that matter, even when reduced to one-millionth part of the density of ordinary air, can become luminous under electrical excitement. [A glass bulb about four inches in diameter, kindly lent to me by Mr. Crookes, was exhibited, in which a metal ball about half an inch in diameter formed the negative pole. Under a suitable condition of the induction-current, this ball was seen to be surrounded by a corona of bluish-gray light which was sufficiently bright to be seen from all parts of the theatre.] Yet it is probable that these tubes must be looked upon as crowded cities of molecules as compared with the sparse molecular population of the great coronal wastes.

I forbear to speculate further, as we may expect more information as to the state of things in the corona from the daily photographs which will be shortly commenced at the Cape of Good Hope by Mr. Ray Woods under the direction of Dr. Gill.

THE RELATIONS OF RAILWAY MANAGERS AND EMPLOYÉS.

By Dr. W. T. BARNARD.

[*Concluded.*]

IN the United States it has not been an uncommon practice for railroad corporations, looking to their own immediate immunity from prosecution, to aid their servants in securing, in various ways, some protection from or indemnity for the effects of injuries received in the performance of duty; but such efforts, being usually spasmodic, and always conditioned upon releasing the company from all liability, have

* For a history of opinion of the nature of the corona, see papers by Professor Norton, Professor Young, and Professor Langley, in the "American Journal of Science"; also "The Sun," by Professor Young; and "The Sun the Ruler of the Planetary System," and various essays, by Mr. R. A. Proctor.

not generally received the cordial recognition and support of the employés themselves; have been ephemeral, and at best have only partially afforded the contributing companies protection from legal responsibilities. Objection has frequently been made to the writer that the conditions under which railroads are operated in the United States differ so widely from those of other countries as to render the experience of the latter of little practical value to us for purposes of comparison and guidance, and this belief seems to be wide-spread. The best possible answer to such an objection may be obtained from an inquiry into the results of the efforts of those American railroads (and there are several conspicuous examples) which, following English and Continental precedents, have *systematically united* with their employés in establishing societies like those which have proved so prosperous abroad. Reference has been made in a previous paragraph to an association of this character inaugurated five years ago by a prominent Eastern trunk line. From the first publication of its prospectus the Baltimore and Ohio Employés' Relief Association attracted marked attention, not only among railroad managers of advanced thought, but very generally among students of social and industrial science and prominent educators, and that interest has been well sustained by frequent reports in the public press of its growth and work. Having in the five years of its existence a sustained membership exceeding 18,400; having, under its various features, distributed over a wide territory more than $929,940.14, in 42,930 separate payments; and combining within itself, in one harmonious system, provision for the relief of the sick, injured, superannuated, and for their families after death; a savings-bank, a building association, a circulating library, and other features of less importance; being a leader in railroad sanitation; and, in short, representing, on the largest scale in the United States, the most popular foreign friendly and aid societies—this Relief Association will best serve for purposes of restoration.

A general review of its theory and provisions is necessary for a proper understanding of the results it has attained, but any specially interested in the details of its organization and management are referred to the secretary of the association at Baltimore.*

In a circular dated May 1, 1880, the Baltimore and Ohio Railroad Company announced that, on the petition of a number of its employés, after a very thorough examination and study of benevolent railway organizations in Great Britain, France, and Germany, having a full appreciation of the advantages which experience has uniformly shown may be enjoyed by the employers and employés of railroad and other large corporations where benevolent relief societies have

* The writer was indueed, some years ago, to publish in the Chicago "Railway Age" an account of the features of this association, then in operation, but to which important additions have since been made. Having but a limited circulation, among railroad people only, that paper has been utilized in the preparation of this article.

been put into operation, it thereby inaugurated an Employés' Relief Association, which was subsequently incorporated by special act of the Legislature of Maryland, June 3, 1882.

The Baltimore and Ohio board of directors, by a resolution guaranteeing the absolute fulfillment of all the promises and provisions of the constitution of the association, made the following announcement:

"To give further force and effect to this plan, and as an earnest of its solicitude for their comfort and welfare, the company has contributed $100,000 as the nucleus of a fund from which its employés can derive pecuniary relief in the event of becoming incapacitated for earning their livelihood, or by means of which, in the event of death, they may leave some provision for their families, upon condition that they will second its endeavor to promote their welfare by making such contributions to the fund as will secure its permanency and effectiveness.

"The company will also, without expense to the fund, give the services of its staff in conducting the clerical and other business necessary to its proper management; office-room for its records, etc.; and, whenever it is necessary or desirable to employ females or children for such work as they are qualified to perform, preference will be given to the widows, wives, sisters, and children of its faithful contributing employés over other applicants in the order above named.

"It will also make arrangements by which the children of those contributing to the fund, under sixteen years of age, shall travel free when going to or returning from school, over all its lines for distances under ten miles, and will give half-fare transportation to contributors, their wives and children traveling over its lines.

"Also, having learned of the pecuniary necessities of persons formerly in its service, and being anxious and solicitous that its present and future employés, although escaping accidents and sickness while in the discharge of duty, shall not find themselves without means of support whenever, through approaching old age or the contraction of infirmities, they become unable to perform the services assigned them or to earn a livelihood in other pursuits, it has added to the indemnity features of the plan its superannuation or annuity provision, which it commends to their consideration and adoption."

Subsequently this superannuation feature was elaborated under a further endowment which nets the association $25,000 per annum, and later on its savings, building, and free circulating library features were guaranteed by and received the liberal support of the company, which is also taking measures to establish a sanitarium and home for its disabled and aged employés and their families, for which a beautifully located and healthy site has already been purchased.

In the preparation of this scheme the selecting and classification of risks were among the earliest and most embarrassing of the questions to be settled. All legitimate life and accident insurance companies,

and indeed all the most solvent co-operative associations, select their risks, upon which they place a limit, imposing their own standard of physical qualifications. Railroads, however, can make no such invidious distinctions against, perhaps, their most deserving servants, and hope to succeed in any insurance scheme they inaugurate. Such a plan must embrace all, if any. In considering percentages of railroad accidents the physical condition of employés is a comparatively small factor—entering but little into cause and effect—because in active railroading, as in army campaigning, the weak and diseased are soon eliminated, and the fittest only survive the exposure and physical strain to which they are constantly subjected. In the five years of this association it has been uniformly found that the standard of health and longevity of railroad operatives is remarkably high, far exceeding that which the insurance tables assign as the average for people of equal age but of unselected occupations. On the other hand, age is a potent factor in determining liability for sickness and death from other causes than violence. Besides the statistics of accidents at its command, the Baltimore and Ohio Company were able to ascertain with approximate accuracy the ages of its employés; and it was thereby enabled to estimate with a reasonable degree of certainty the risks to be incurred and provided for. Then, after allowing the employés a reasonable time within which to enter the association without questioning their age or physical condition, it adopted and has since rigidly enforced the policy of employing for its service none over forty-five years of age, and who can not pass a strict medical examination. Among other immediate results of this measure, the average age of many thousands of employés has been reduced to twenty-eight years, and the standard of their physical strength and activity perceptibly advanced, to the company's obvious gain and the lessening of the liabilities of the relief association, which were predicated upon the average age and health of the company's employés when the average of age was much higher and their standard of health lower than now. This has resulted in largely increased benefits without increasing premiums, and has rendered the company's guarantee, as regards the *relief* features, practically a nullity. The premiums and benefits under the relief feature of the association were predicated upon a simple classification of the employés according to hazard of occupation and accustomed compensation. It was recognized that the laboring classes of this country are familiar with larger sums of money than are foreigners, and are therefore apt to regard with indifference the net earnings of premiums that would be deemed considerable abroad; and because adequate protection against the wants of life affords great security against harassing and costly litigation with the employers, it was thought desirable to fix the standard unit sufficiently high to give substantial relief, while yet not allowing such large benefits as would require oppressive taxation of the employés, or as would offer temptations to practice fraud or deceit

by pretended disablements. The benefit must also be tangible and fixed, to obviate discontent; for, as a rule, the people engaged in manual labor are suspicious of indefinite insurance, and dread being taxed for unknown quantities—the employés of the company were therefore divided into two classes—the first class containing those engaged in operating trains and rolling-stock, and the second containing all those not so engaged; and the unit of premium was fixed at twenty-five cents per month per rate, for each feature, or seventy-five cents for the three features of the lowest rate, increasing in the ratio as given in the table on page 773.

Members may now secure insurance under this feature to the extent of thirty rates, or six thousand for a premium of twenty-five cents a rate for death under benefit 5 only.

It was provided that, while no employé could take the benefits of a lower class than those to which his salary assigned him, he could take as many more rates (up to the limit) as he chose. Also that such of those employés in the service at the time of the inauguration of the association as did not desire to take the three, could yet, as they elected, enjoy the benefits of one or more features; which brought within the reach of all, on a uniform and simple scale, protection commensurate with what they could spare to secure it.

The manner of collecting premiums next demanded consideration. As no initiation fee could, with propriety, be exacted of those newly seeking employment for a livelihood, so none could properly be collected from those already in the service; and as, for obvious reasons, it was undesirable to ground the plan upon a capital stock company, it became necessary to mainly depend for assets upon the payment of premiums. By the simple expedient of requiring premiums to be paid in advance, there would always be on hand the maximum sum required to pay for the casualties of the following month, and this was also thought to be the least onerous and therefore the best form of subscription.

The liabilities and benefits of members being well known, premiums could be deducted from their wages on the monthly pay-roll, and thus all risk through the handling of funds by irresponsible parties was avoided, and the Baltimore and Ohio Company became responsible for the collection—the association being credited on the company's books with the premiums which remain in its custody until withdrawn by legitimate warrant. No large sums are allowed to accumulate, the surplus not needed for immediate wants being invested by the committee of management from time to time in first-class securities. It was believed, and the result has fully proved, that premiums thus collected, while subject to the scrutiny of every interested person, would be paid with less reluctance than after the money had passed into the actual possession of members, and in many cases they would not be conscious of having made any contribution at all.

SALARIES.	PAYMENTS PER MONTH.	BENEFITS.				
		1.	2.	3.	4.	5.
		In case of temporary disablement by accident, while in the discharge of duty, the monthly payment, for a period not exceeding six months, of	In case of permanent disablement and incapacity to resume employment, arising from accident while in the discharge of duty, the monthly payment (after the sixth month) during continuance of such disablement, of	In case of death, arising from accident while in the discharge of duty, the payment to the legal representative, within sixty days after death, of	In case of injury or sickness, from any cause other than accident while in the discharge of duty, causing total inability to labor, the payment (not longer than one year) of a daily allowance of	In case of death, arising from any cause other than accident while in the discharge of duty, the payment to the legal representative, within sixty days after death, of †
		Per day.	Per day.*			
1. Those receiving $35 and under per month should pay.....	1st class $1 00 2d " 0 75	$0 50	$0 25	$500 00	$0 50	$100 00
2. Those receiving $35 and not more than $50 should pay.....	1st " 2 00 2d " 1 50	1 00	0 50	1,000 00	1 00	200 00
3. Those receiving $50 and not more than $75 should pay.....	1st " 3 00 2d " 2 75	1 50	0 75	1,500 00	1 50	300 00
4. Those receiving $75 and not more than $100 should pay.....	1st " 4 00 2d " 3 00	2 00	1 00	2,000 00	2 00	400 00
5. Those receiving $100 should pay....	1st " 5 00 2d " 3 75	2 50	1 25	2,500 00	2 50	500 00

* Including free surgical and hospital treatment.

† Subject to increase predicated upon surplus at end of each year, now double this stated allowance.

A much graver matter was that involving the question whether membership should be made compulsory upon employés of the company, and, if at all, to what extent. It is believed to be a fact that neither abroad nor in this country has an accident railway association —although some have carried heavy endowments—been successful for a long term of years except where membership has been made compulsory. Many have been organized, and have lived for longer or shorter periods, but their sphere of usefulness is always very limited, and they gradually become inefficient and fall into disrepute or have to be reorganized at the sacrifice of good faith to old members.

It was urged upon the management that they should use all proper means to induce membership on the part of those already in the service, and that the company should adopt such measures as would at least insure a thoughtful consideration of the benefits offered its employés. It was finally determined to adopt a modified compulsory policy, the ultimate effect of which would be to bring within the association every employé of the company. It is this compulsory feature which makes the association unique, and which guarantees its permanency and continuous success. It is undeniably within the strict bounds of propriety for the management of a railway or any other corporation to specify the conditions upon which it will employ, and to decline the services of those who show no disposition to protect themselves and families against the vicissitudes of the service they seek to enter. But to inaugurate such a policy at that particular time was to trespass upon very delicate ground, and required no little determination, for the railroads of the country were just recovering from the prostrating effects of the strike of 1877, and were cautiously re-establishing the *status quo*. This new departure from preconceived ideas and practices of dealing with labor was watched with great interest by railroad officials and others accustomed to dealing with the grave issues constantly arising from the employment of large bodies of men, and it was amid many predictions of failure that the announcement was made that the company would thereafter require as a condition precedent to employment that those seeking service should enter the insurance organization. It started a very lively discussion as to the merits of the scheme, and forced those to examine its provisions who would otherwise have passed them by with indifference.

Upon careful examination of the foregoing tabulated statement it will be noted that contributions are, in all cases, deducted monthly from the members' wages, so that payments are required of them only when they have earned wages, and the allowance is, in all cases, proportioned to the monthly contributions paid by each person in the several classes into which the contributors have been divided.

In cases of disablement the allowance is paid not less than once every month; before each payment, whether for temporary or permanent disability, satisfactory evidence of its existence being required.

The notification of disablement, which precedes all applications for temporary or permanent allowance, is made upon and in consonance with forms furnished for that purpose; when it is the duty of the head of the department, or supervisor of division or section, under whom the member serves, to certify whether the disablement was received in the discharge of duty and in the company's service, and to forward a certificate to that effect to the secretary of the association, accompanied by a similar certificate covering the clinical facts from the society's surgeon called to attend the member.

The managers, from time to time, adopt such measures to secure the proper visitation of contributors on the allowance list as they think proper, and no member refusing to submit to an examination by such visitor is entitled to receive any benefits from the fund during the continuance of such refusal.

To constitute a lawful claim for accident indemnity, there must be:

1. Exterior or patent evidence of injury, and satisfactory testimony that it resulted from accident while in the discharge of duties assigned the contributor by the company, and incapacitates him from earning a livelihood.

2. In case of death, that the injuries sustained by such accident were the sole and direct cause of death; or—

3. Not resulting from accidents while performing the company's service, that it was not caused by injuries received while engaged in unlawful enterprises or riots. The managers are the exclusive judges as to whether the injuries have been so caused and received, and their decision shall be final and conclusive.

All legitimate claims for death-allowance are paid in full, irrespective of any previous payments which may have been made under the head of temporary disability allowance, but the managers have power to require such information and particulars as they deem necessary to establish the validity of the claim of any person applying for allowance.

In urgent cases the managers have power to pay part of the death-allowance within a shorter period than sixty days, but the whole is always paid within that time.

In the event of a contributor, who has been injured while in the line of duty and in the company's service, resuming work and afterward dying from the effects of such injury, the fund is liable for the payment of the accidental death allowance, according to the scale, should death occur within a period of six months from the date of injury; but, after that interval no further liability attaches to the fund with regard to the payment of the accidental death allowance. Any contributor, who, by reason of continued sickness from natural causes, or resulting from accidents incurred while not on duty, is unable to work, is entitled to death-allowance according to the scale and provisions relating thereto; if death occur no later than one month

after the time for which payments have been made, and if it can be shown to the satisfaction of the committee of management that such person has not worked elsewhere during any part of the intervening time.

Each contributor is given a certificate setting forth his rate of contribution, and the measure of relief to which he is entitled; which is valid during the period the holder remains employed by the Baltimore and Ohio Railroad Company, or by other companies to whose employés the benefits of the fund may be extended; which certificate is to be exchanged or modified from time to time, so as always to represent the grade or standing of its holder in the fund.

The death-allowance is paid to the person designated by the contributor in his application; but, if there be no such designation, then to the legal representative of the deceased.

The several subscriptions to the fund are deducted monthly, or whenever salaries are paid by the company's paymasters in advance, and are held subject to investment or disbursement as the managers may decide.

In order to secure to the railroad company that immunity from prosecution which its liberal contributions for the protection of its employés' interests entitle it to enjoy, it was further announced that it was not contemplated to give double benefits in those cases of disability or death resulting from accidents; the promised benefits would not be paid when the contributor or any person entitled to damages because of the accident to him, whether resulting in death or not, claimed damages against the company; and requiring the filing with the managers of the association of a release satisfactory to them, signed by all persons in interest, releasing the company from all liability; but it was left optional with the employé to accept the benefits offered by the association, or to institute other measures to secure indemnity for injury sustained.

Every applicant for membership is required to state in his application his age and length of service with the road, or its branches, which is held to be conclusive evidence in respect to any subsequent claim presented by him or his representative.

Before any accident allowance can be paid to any member, the surgeon of the association must certify that he is totally unable to labor; and the supervisor or chief of division or department in which he served before the accident must certify that his injuries were received while in the discharge of duty and in the company's service.

In cases of illness or diability not thus incurred, the allowance is paid only after certificates, satisfactory to the managers, have been received from a duly registered medical practitioner, corroborated by the contributor's superintendent, or the head of department, that sickness or injury had caused total disability for labor for the time specified in the certificate.

The moneys belonging to the funds of the association not required for immediate use are invested by the managers in United States bonds, Maryland State and municipal bonds, Baltimore and Ohio Railroad bonds or obligations, or other first-class securities. All securities and the moneys necessary to meet current expenses are intrusted to the official custody of the Treasurer of the Baltimore and Ohio Railroad Company, to be held subject to requisition of the committee of management.

The managers are chosen partly by the Baltimore and Ohio Railroad Company, on account of its interest in the fund, and partly by the contributors to it; the company choosing four and the contributors five —the majority of those selected.

Any differences arising between claimants for the benefits set forth in the constitution and the committee of management are submitted to arbitration.

The condition of the fund is annually investigated and reported on by a proper and competent person, to be selected by the managers for that purpose, and any surplus remaining at the end of each year is devoted to the reduction of the rates of contributions of members, or in such other manner disposed of as in the judgment of the committee will best subserve the interests of the association.

The association utilizes, under judicious contracts, those hospitals located, and those physicians and surgeons residing, along the company's lines, and this service has been economical and agreeable to its members. While it is responsible for surgical expenses only in cases of injury arising from the discharge of duty, its members have the advantage of reduced prices obtained under its contracts when they are otherwise disabled or sick. There are besides, as a part of the staff of the society, a corps of salaried physicians designated as medical inspectors, to each of whom is assigned territorial limits, which they are constantly traversing, investigating cases of disability, methods of treatment, the sanitary condition of the lines, etc. It is also their duty to afford prompt relief to sufferers from casualties of travel, whether they be members of the association or other employés, or passengers; to examine applicants for admission to the company's service as to physical qualifications, and to exercise a rigid censorship over the sanitary conditions of grounds, buildings, coaches, baggage, etc.

The rigid sanitary supervision exercised by the association through its medical inspectors over every portion of the line enables it to check and control many disorders before they have assumed grave proportions. Thus, some years ago, when small-pox was prevalent at many points tapped by the Baltimore and Ohio system, over twelve thousand employés (and in dangerous localities their immediate families) were vaccinated by the medical inspectors at association expense, and, though many employés were greatly exposed to contagion, less than a dozen were affected, and but two died from the disease. It is somewhat remarkable that nearly eighty-five per cent were successful vaccinations

or revaccinations. When diarrhœal, dysenteric, and typhoid disorders become prevalent at any point, they are immediately checked by appropriate remedies placed at the disposal of the medical inspectors, master-mechanics, and supervisors, with explicit directions for use. Malarial disorders, especially, have been kept well under control by the distribution of large quantities of approved anti-periodic remedies, which are at the command of every member, and thereby much embarrassment and inconvenience to the service has been prevented.

Another and popular feature recently inaugurated is the free circulating library, which already has nearly five thousand volumes, selected with special reference to the wants and tastes of the employés and their families, and purchased from private subscription of officers of the company.

Many of the employés reside at points remote from towns, and have no opportunities for procuring literature adapted to their tastes, and when thrown out of their accustomed occupation by sickness or accident, without resources for entertainment, the minds of many men brood over their misfortunes to an extent that seriously retards recovery. To such, anything that diverts the mind from care or trouble is unquestionably of therapeutical value. Other employés also are furnished with educational and technical works, especially adapted to the requirements of engineers, mechanics, firemen, road, and all other classes of workmen, and those who wish to improve their leisure hours, by studying such works as will increase their professional business knowledge, are supplied under conditions which do not necessitate their leaving the society and comforts of their homes, and many employés, therefore, avail themselves of this chance for qualifying themselves for promotion and advancement in life, while at the same time their children, wherever located, have at command facilities for study, and instructive reading matter seldom obtainable outside large cities. The library also undertakes to purchase for members stationery, school, text, and other books at cost price, giving them the benefit of discounts on large orders and free transportation. The plan under which this library is operated is very simple, inexpensive, and effective, and could be put into operation on all our roads at nominal expense. Inexpensive but carefully prepared catalogues are printed; also cards on which to make requisitions for books, so distributed that every employé can select, order, receive, and return literature without delay through the company's train-service. Library committees, composed of employés, are organized at divisional and all other large stations, and through them, direct or by the aid of officials of the company, any workman, or any member of his family, however isolated, is readily supplied.

In pursuance of the policy of the company to improve the secular, moral, and intellectual welfare of its forces by every means in its power, well lighted and heated reading-rooms have been provided at several principal stations where employés may assemble for social in-

tercourse, or for reading and writing, and these rooms are well furnished with the principal daily and monthly periodicals, as well as with weightier matter. It is in contemplation to provide them at other divisional stations.

Like the relief features the savings-fund and building features are operated under fixed laws by a board, the majority of whom are contributing members, and are equally fostered and guaranteed by the railroad company.

Among the inducements offered by the savings feature are:

Facilities to members and their wives, no matter how isolated their location, to invest savings or to make temporary deposits in the fund; and they may make deposits in larger sums and with more frequency than allowed by other savings-banks.

Avoidance of loss of time and of trouble in reaching places for depositing and withdrawing money, depositories being located at intervals along the line, averaging less than twenty miles.

Allowance of interest, generally greater than, and always equaling, that given by other savings-banks.

Ability to draw checks against balances, as in other banks, wherever on the line a depositor may be; to obtain, in place of deposits, checks of the Baltimore and Ohio Company negotiable anywhere, and to withdraw deposits, wholly or in part, with accrued interest, with promptness and certainty, under the legally binding promise of the Baltimore and Ohio Company.

Participation in all profits earned by the operations of the fund—every permanent depositor being substantially a stockholder, without liability or any of the legal responsibilities usually attaching thereto—and under the most favorable conditions for the economical, faithful, and wise administration of the fund through the offer of the Baltimore and Ohio Company of the services of its bonded and other officials, and the designation of experienced, able, and conservative directors to invest its moneys, and generally to manage its affairs.

Under the building feature: Opportunity for every member of the association, not only those who can provide collateral for loans, but also those who have no real estate or other security to provide or to improve homes for their families, by borrowing from the savings fund at the uniform rate of six per cent interest, and upon the easiest terms as regards repayment of principal, viz.: in monthly installments of one dollar upon every hundred dollars borrowed, with the option to borrowers of making larger repayments.

Payment of interest, not upon the whole sum borrowed until all the loan is repaid, but only the payment of six per cent per annum upon so much thereof as, at the commencement of each year, remains unpaid—an advantage over most building societies.

Certainty of securing valid titles and conveyancing, searching records, recording deeds, etc., at minimum cost, through the employ-

ment of the company's numerous counsel resident in various localities.

Free and complete possession of property purchased with loans from the savings fund during the repayment of the loan; thus substituting the repayment of loans for the payment of rents, and acquiring ownership of homes at little or no additional monthly payments.

Ability to purchase materials at large reductions upon current rates, through contracts made by the association with wholesale dealers for building and other material in large quantities.

Opportunity to utilize, free of cost, the officers of the association as agents in negotiating real estate and other transactions, such as securing fire and life insurance at reduced rates, prompt payment of taxes, water-rates, etc., etc.

Reduced transportation for all materials entering into the construction or improvement of homesteads.

For those who have nothing to offer as security for loans, a plan for enabling them to secure homes by simply insuring their lives for the ultimate benefit of their families is provided.

Those leaving the company's service can continue their payments as before, or can dispose of their interests to the best advantage, as can also those unable to meet their payments.

Many other minor provisions, all looking to the comfort and welfare of its members, have been added to this association from time to time, but their enumeration is unnecessary here. To summarize briefly the benefits conferred by this institution under its relief features:

It enables employés to avoid selecting insurance organizations unworthy of confidence, and to avoid forfeiture of their moneyed interests, as premiums are only deducted from month to month, and are monthly expended in giving immunity to the well and indemnity to the disabled. The plan of periodical deductions enables them to make payments of premiums with definiteness, certainty, and regularity, in such small installments as not to be felt, and on a scale which the company has obligated itself shall not be increased. They have the company's guarantee that all benefits promised shall be faithfully paid. The premiums are so graduated that the poorest can enjoy membership and advantages proportioned to their contributions. It relieves employés from all necessity of soliciting contributions, prevents restlessness, discontent, and hardship resulting from inability to earn wages under bodily infirmity; and the knowledge that when in distress they get their dues promptly, and not through charity, and that their families are adequately provided for against immediate want in case of their death or disablement, makes the men more cheerful, efficient, and contented. On the other hand, it does away with all appeals to the personal or official charity of the management, and with claims for indemnity for accident, and relieves the company from nearly all the costs and embarrassments of suits instituted by employés.

The library exerts an elevating and educating influence on the employés of the service, and particularly upon their children, the value of which can only be estimated by those acquainted with the dearth of school facilities, and the ignorance prevailing in the mountain-regions of Maryland and Virginia, and generally throughout West Virginia.

The effect of the savings and building features in inculcating and encouraging prudence and thrift will be readily recognized by us all, who know by experience that there is more need to learn the art of saving money than of earning it. By their means the humblest laborer can provide against seasons of adversity, or if he pleases may provide a home for himself and family and take that rank and independence among his fellows that attach everywhere to freehold and freedom from debt; and all this, under circumstances of convenience, cheapness, and absolute security that none but—and not many of—our metropolitan cities can offer. As illustrating the avidity with which the employés of the Baltimore and Ohio Company are utilizing these new features, it is reported that the savings fund had received in deposits $273,132.59, of which $159,440.88 have been loaned under its building feature, and only $26\frac{35}{100}$ per cent of deposits have been withdrawn since the bank was opened.

The benefits accruing to the Baltimore and Ohio Company through the formation of this association were early demonstrated to be material and important. Though at first there was opposition from some employés caused by a misapprehension of its provision, and unjust, harsh, and ignorant criticism from newspapers inimical to the Baltimore and Ohio management, the end of its first year showed a membership excelled by few if any benevolent societies in the United States, and at the end of its fourth fiscal year ninety-five per cent of all the company's employés — other than clerks, telegraphers, and agents, non-hazardously employed—were enrolled.

While before its establishment the Baltimore and Ohio, like all other railroads similarly situated, directly or indirectly, yearly disbursed large sums for damages to its employés, and was subjected to much annoyance and loss by the angry feelings engendered by litigations with its people and their friends, since 1880 it has not had a dozen such suits, and this almost total immunity from vexatious litigation with its employés has of itself been a saving of several times the entire expenditure on the association's behalf.

Through the system of medical examination of applicants, through the improved sanitary condition of its shops, through the consideration and care and compensation paid employés when disablement necessitates cessation from labor, and through the prompt payment of sufficiently large death insurance, the standard of the service has been perceptibly raised, and it is securing a much more efficient and desirable class of labor, skilled and unskilled, and has, in some places, drawn the best material from competitive works, and holds its force with

less difficulty and loss. It is the bond of closer friendly relationship between employer and employé, and has fostered a feeling that the interests of both are identical. It has done away with all pretext for joining organizations inimical to labor, as well as with all justification for seeking charitable assistance from the company or from fellow-employés.

It is the almost unanimous testimony of the railroad company's officials that it would now be most difficult, if not impossible, to inaugurate a general strike among the members of this association.

Personal appeals to the managers of the company for pecuniary assistance on behalf of unfortunate employés are now unknown in this service, and this relief from solicitation has reacted favorably upon the *morale* of the force by inducing independence and contentment. Besides the many patent advantages accruing to the company from the savings fund and building features, is the important one of converting a proverbially migratory force into a permanent one, which is gradually locating itself at points where the company's interests will best be subserved and protected.

Under the pension feature the provision made for the support during life of its aged and permanently disabled employés enables the company to dispense at will with many old servants, who, though incapacitated by mental or bodily infirmity, often the effect of injuries received in the service, must, under ordinary conditions, through sheer humanity, be borne on the rolls, though, as all administrative officers know, to the disadvantage and frequently to the endangering of the company's interests.

In brief, the best possible testimony of the good results attained lies in the fact that, as the result of two years' trial of the plan, such a conservative corporation as the Baltimore and Ohio Railroad Company undertook further obligations on its behalf which, if capitalized, would amount to over a half a million dollars, and is contemplating still further donations to the same cause.

Railroading is rapidly advancing beyond the boundaries of a mere business, and into the dignity of a profession requiring extensive knowledge of many branches of science, technical training of a high order, and already requires a devotion to corporate interests from its staff-officers and many subordinates that necessitates the sacrifice of their independence, and all opportunity of securing competence in other channels, while it has not branches or departments in which intelligence, energy, and scrupulous honesty are not required. And, as of the great armies of railroad operatives only a few, comparatively, can gain wealth or competence, the great majority who give to their work equal devotion and their full measure of ability yearn for recognition in their sphere, and in no more effective or acceptable way can they be rewarded than that in which the Baltimore and Ohio Railroad has recognized the self-abnegation and faithfulness of its servants.

Let other railroads follow their example. Let them do away with nepotism in employment and promotion; accept the services only of those found to be expert workmen, physically as well as mentally qualified to fill responsible positions; then surround those selected with such material protection and attractions as will annul migratory instincts and anchor them by chains of self-interest, and they will have made safe provision against such disasters as that which overtook some of our Eastern lines in 1877. The motive of a railroad in thus meeting its employés more than half-way need not be concealed. It is far better to have it at once understood that self-interest is to be the governing consideration on both sides; that as the employé expects to profit by his participation in such a scheme, so does the railroad, from its participation therein, not at the expense but through the promotion of its workmen's interests. The latter, by yielding a small percentage of their pay, can secure to themselves all the benefits derivable from the most judiciously prepared scheme of insurance and mutual benefit that the light of the present age can afford; the former, through the annual investment of a reasonable sum, probably to the saving of larger expenditures in other directions, will profitably secure itself against the annoyance of lawsuits and other ill results, while also reaping other advantages and forwarding the philanthropical work of the age. The student of railway benevolent institutions abroad will be struck by the disparity of growth between those in which insurance against accident, old age, and death is by the employer made compulsory upon the employé, and others where such action is optional in favor of the former. In old settled countries, where the labor market is overstocked and competition for place most active, little difficulty is experienced in enforcing such a prerequisite to employment; but in this country, where the rapid development of railroad interests usually creates a constant *demand* for labor, and where the dissatisfied employé of one road has only to step across the field, as it were, to be welcomed with perhaps increased pay by rival interests, it takes nerve to enforce such a provision. There are few intelligent railroad managements that will not fully admit that, as the result of proverbial improvidence, their employés are, as a class, discontented, migratory, and exceptionally difficult to reach with moral and economical teachings; and they must clearly perceive, in the words of a recent writer, that "there is marked tendency to trust to luck in the future for themselves and their families, instead of making provision ahead, which exercises a demoralizing effect upon the whole character, and directly affects the interests of their employers." Yet, though they are prepared to admit that this fact makes it both right and a duty of the employer to interfere to correct the evil, as far as it is possible to do so, and that "if men need to be made provident, and to guard against adversity in sickness and old age by compulsion, then compulsion should be used," they are naturally slow to force an issue not

absolutely vital, and which they fear may deprive them of help at time of need. The danger is, however, more imaginary than real, for no one will deny the right of a corporation, or any employer contracting for labor, to impose such conditions as a precedent to employment as its interests and judgment dictate, and to select preferably those willing to help protect themselves and dependents from the effects of a hazardous service. The great success of the Baltimore and Ohio Employés' Relief Association lies in the fact that the managers of that company "had the courage of their convictions," and made it a condition precedent to employment in its service that the men should sign an agreement to protect themselves and families against the vicissitudes of a hazardous service.

The proverbial conservatism and timidity of capital make it slow to realize the logical sequence of experiments which have a vital bearing on its invested interests. The uniform success and increased prosperity which have attended industrial partnerships between capitalists and their workmen—practiced more extensively on the Continent of Europe than in England, and little or not at all with us—show to the disinterested, thoughtful mind that herein, more than in efforts in all other directions combined, excellent though their effect may be, lies the true solution of the gravest and most important question pending before the world—i. e., how to equitably adjust the relations between capital and labor. Probably the serious contemplation of a division, no matter how minute, of their profits with those whose labor made them, would incite in the minds of our railway share and bond holders such alarm and opposition as would displace any management advancing such a proposition; yet on one or more of the most important railways in France judicious action in this direction has resulted in the employés becoming the majority owners of the securities of the properties they operate, and those corporations and firms in whose profits their workmen are allowed to participate have experienced increased prosperity and decreased migration and irregularity in attendance of the workmen, whose general standard of efficiency has been raised by the competition to share such benefits, and this unity of interests has entirely isolated them from the effects of labor agitations and turmoils. That the managers of such great interests as those of our railroads and mammoth manufacturing establishments who pioneer a reform of this character must possess great nerve and resolution as well as influence, goes without saying; but the constant strife and competition now prevailing, necessitating most rigid economies, which almost always result in curtailment of wages and in strikes, must of themselves gradually force corporations to concert measures for securing permanent control of their forces, and none can be so effective as those that look to a community of financial interests. The manager who first succeeds in applying to his service the principle of industrial partnership will prove a Napoleon in the railroad world and a dictator to

all competitors. That some one competent, and of influence sufficient to direct such a movement, may shortly arise, is not altogether improbable, for already the president of one of the great Eastern trunk lines, when recently recapitulating what his board of management had done to cultivate such attachment in its employés, said:

"I hope to see the day when this society will be extended into a great co-operative association; when the men in this service will individually have pecuniary interests in this vast property; when the men who run the trains and operate the machinery, and all others having steady employment, will be part owners in this great corporation; when they will in every sense be identified with and form a part of this company."

TOMMASI-CRUDELI ON MALARIOUS COUNTRIES, AND THEIR RECLAMATION.*

DISMISSING from scientific terminology the words "marsh miasm" and "marsh soil," and replacing them by "malaria" and "malarious soil," the author traces the fever-poison thus indicated to "an agent which can infect the soil of any country, however that soil may differ from other soils in hydrographical and topographical conditions and geological composition."

This agent is a living organism inferred to exist long before microscopy. That its character should remain uniform in soils the most diverse proves that it can not result from the chemical reaction of these soils. This persistent uniformity is easily understood on the admission that malaria is due to a fermentative organism which finds conditions favorable to its life and its multiplication in soils the most various, as is the case with thousands of other organisms much higher than the rudimentary vegetations which constitute living ferments.

The increasing intensity of the poison in malarious soils abandoned to themselves is especially demonstrable in Italy. Etruscan and Latin cities—Rome herself—arose in malarious regions, and they flourished mainly on account of the soil reclamation, which in the course of centuries diminished the production of the poison, without, however, succeeding in wholly suppressing it. The abandonment of the reclaiming processes led to the redevelopment of the poison—first during the Roman domination in the conquered and devastated Etruria, afterward in Rome herself on the fall of the empire, and finally in Southern Italy. This redevelopment of malaria in the Roman Campagna has been witnessed in times not very remote from ours, localities where it was possible to enjoy summer residence (*villeggiatura*) having at that season become uninhabitable. In these localities the physical condi-

* Abstract by the "Lancet" from an article published in the "Nuova Antologia."

tions of the soil have not varied for centuries; how, then, can the enormous increase of malaria be due to progressive alteration in the chemical constitution of the soil itself? Admit that malaria consists in a living organism whose successive generations infect to an ever-increasing extent the soil which contains it, and the explanation is easy.

Again, in regard to the malarious contents of the atmosphere. If the malarious ferment (*fermento malarico*) were composed of gaseous emanations from the soil, or of a chemical ferment formed in the soil and raised into the air together with watery vapor, the malarious contents of the atmosphere ought to reach their maximum in those hours when the soil is most warmed by the sun's rays, and in which the evaporation of the water it contains and the chemical processes occurring within it are at their greatest intensity. But it is not so. The malarious contents of the local atmosphere are less in the noonday hours than at the beginning and close of the day—that is, after sunrise and, above all, after sunset. Now, it is exactly at these two periods of the day that the difference between the temperature of the lower strata of the atmosphere and the temperature of the surface of the soil is greatest, and that the currents of air which ascend vertically from the soil into the upper atmosphere are at their strongest. Admitting that the malaria is formed of solid particles of low specific gravity (such as are the germs of the inferior vegetations), we see at once how it ought to accumulate in the lower strata of the atmosphere, especially in those two periods of the day.

The tendency among investigators has always been to attribute this specific poisoning of the air to a living organism which multiplies in the soil; but, unfortunately, the "palustral prejudice," as Dr. Tommasi Crudeli calls it, has led them to examine only the lower organisms which haunt marshes. In 1879 the author, in conjunction with Dr. Klebs, discovered the cause of malaria in a "schizomyces bacillaris," and recently Drs. Marchiafava and Celli have demonstrated that this parasite attacks directly the globules of the blood and destroys them after having determined in them a series of characteristic alterations, which indicate quite certainly the existence of a malarious infection. "Many observations," says the author, "just completed in Rome, would tend to demonstrate that this parasite does not invariably assume the bacillary form described by Klebs and myself; but this purely morphological question need not concern the practical hygienist. For him it is essential to know that he has to deal with a living ferment which can flourish in soils the most diverse in composition, and without the presence of which neither marshes nor pools of putrescent water are capable of producing malaria."

Having incidentally shown that soils may contain this parasite in an inert state and not produce malaria till the circumstances favorable to its activity have arisen, Dr. Tommasi-Crudeli proceeds to demon-

strate that among the conditions which assist the development of the malarious ferment contained in the soil and the excessive air accumulation of that ferment in the air, there are three of primary importance, as their concurrence is indispensable to the production of malaria. These are (1), a temperature not lower than 20°C. ; (2), a moderate degree of permanent humidity in the malarious soil ; and (3), the direct action of the oxygen of the air on the strata of the soil which contains the ferment. If one only of these three conditions be wanting, the development of malaria becomes impossible. Now, this is an important point in the natural history of malaria, as giving us the key to the chief part of the soil reclamation attempted by man.

First, let us take Nature's amelioration of the malarious countries, suspending as she does for a longer or shorter time the production of malaria. Winter, for example, causes in all these countries a purely thermic amelioration—that is, it suspends the production of malaria simply by making the temperature fall below the minimum required for the development of the poison. In fact, there are often, even in winter, sudden outbreaks of malaria when a sirocco-wind raises the temperature above this minimum. Again, during a very warm and dry summer, malaria is not developed, because the sun's rays have exhausted the humidity of the soil, so producing a purely hydraulic amelioration, which, as in the Roman Campagna, in 1881–'82, may last for a considerable time ; easily to be dissipated, however, by one steady shower. Finally, there may occur in nature purely atmospheric ameliorations, when the surface of the malarious soil is withdrawn from the direct action of the oxygen of the air by means of natural earth-coverings formed by alluvial deposits of healthy soil, or by means of the "earth-felt" wrought up from the soil by the roots of herbage in a natural meadow.

In their various attempts to suspend the development of malaria from the soil, men have tried to imitate Nature—to eliminate, that is to say, one of the three conditions indispensable to the multiplication of the specific ferment contained in that soil. Naturally enough, they have never attempted thermic ameliorations, such as Nature effects in winter, because it is not in their power to control the sun's rays. They have had to restrict their efforts to either hydraulic or atmospheric ameliorations ; but sometimes they have succeeded in happily combining the one and the other—that is, in eliminating at once the humidity of the soil and the direct action of the oxygen of the air upon it.

Hydraulic amelioration has assumed many forms, according to the nature and site of the malarious soil. Drainage, in which the ancient Romans excelled us, has been practiced in Italy both in deep and friable soils and in subsoils compact and almost impermeable, in which latter the "cunicular" drains of the Etruscans, Latins, Volscians, and Romans might even nowadays be studied with advantage.

Sometimes a twofold drainage of the upper, as well as the under aspect of the soil may be practiced—that is, draining the subsoil and increasing the evaporation of the surface water. The cutting down of forests in malarious countries has often proved an excellent means of amelioration; because, by removing every obstacle to the direct action of the sun's rays on the surface of the soil, its humidity during the warm season is sometimes entirely exhausted. In spite of universal experience of this fact, a school originating with the great Roman physician, Lancisi, has sustained the contrary, counseling the maintenance and even the extension of forests in malarious countries. Lancisi was completely possessed with the "palustral prejudice," and believed that the malaria generated in the Pomptine Marshes, and attacking such townships as Cisterna, was intercepted, if only partially, by the forests between, and he therefore opposed the cutting down of the trees and recommended increased planting. He did not know that the malaria was already in the soil and covered by the forest in question. Some thirty years ago the Caetani family, to whom Cisterna belongs, cut down the forest, and twenty years thereafter Dr. Tommasi-Crudeli was able to show that the health of the neighborhood had greatly improved in consequence. A commission appointed by the Minister of Agriculture investigated the whole subject of the coexistence of woods with malaria, and in its report issued in 1884 completely disproved the theory of Lancisi and confirmed that of Dr. Tommasi-Crudeli.

Absorbent plants have been suggested and used as a means of drawing humidity from the soil, not without success in certain countries really malarious. The prejudice that the malaria is due to the putrescent decompositions of the soil has, in Italy, led to the choice of the *Eucalyptus globulus* as the tree best adapted to combat the poison, the idea being that the eucalyptus, which grows very rapidly, dries the humid earth, and at the same time by the aroma of its leaves destroys the so-called miasmata. No genuine instance of the eucalyptus having succeeded in its allotted task is yet known to Dr. Tommasi-Crudeli, though he does not say that its success is impossible. Had its Italian patrons studied its action in its native Australia, where it flourishes much better than in Italy, they would have known that there are eucalyptus forests in those latitudes where malaria is very prevalent, as has been shown by Professor Liversidge, of the University of Sydney. The cultivation of the tree at the Tre Fontane, near Rome, which it was thought would prove entirely successful in combating the local malaria, disappointed expectations, for in 1882 that hamlet was the scene of a severe outbreak of the fever, while the rest of the Campagna was unusually exempt from it. The eucalyptus, in fact, is a capricious tree in European soil; while in full leaf, during the winter, it is often killed by nocturnal frost, and even by the late frosts of spring, to say nothing of humid cold and other adverse influences not

yet formulated by the botanist; again, when the winters are mild and the soil deep, it often shoots up rapidly, only to be snapped asunder by winds of moderate strength. Eucalyptus plantations, moreover, are very costly. If the ground is watery, it has to be drained, otherwise the roots rot; if the ground is heavy, trenches must be dug in it to make room for the long roots of the trees, and often these trenches have to be drained, as is done in the case of olives, in order to prevent the filtration water from stagnating and the roots from rotting. Hydraulic amelioration must have recourse to means less uncertain; and should the conditions of any locality counsel a trial of an absorbent plantation, it should be done with trees of our own hemisphere. The expense is smaller, and the trees are sure not to die.

At best, hydraulic amelioration is never certain, because the slight humidity of the soil necessary to develop malaria may easily be restored to it, even during the warm season. Combination of atmospheric with hydraulic amelioration has therefore been tried: to withdraw, that is to say, the humidity from the soil, while at the same time preventing the direct contact of the air with its malarious strata. Leaving the soil with layers of sound earth spread over it either alluvially or by the hand of man, and also draining the soil itself, was last year, at the instance of Dr. Tommasi-Crudeli, practiced on the grounds of the Janiculan Hill, near the Palazzo Salviati, in the Lungara. The entire area, having been thoroughly well drained and then covered with a dense coating of meadow soil in all those places which could not be paved with street rubble, has since remained without a single case of fever in the numerous *personnel* of the Military College occupying the Palazzo Salviati, while in the Palazzo Corsini, on the same side of the Lungara, but looking on the grounds of the Janiculan which are still exposed to the air and sun, there have within the same period been not a few cases of fever, some of them fatal.

THE ENERGY OF LIFE EVOLUTION, AND HOW IT HAS ACTED.

By Professor EDWARD D. COPE.

HAVING pointed out in a previous essay the lines of descent of vertebrata which have been brought to light by paleontological investigation, I propose to produce in the present article some evidence as to the nature of the forces which have been actively at work in effecting those changes of structure which constitute the evolution of one type of animal from another. We can obtain this evidence by comparing the successive steps of each line with one another. We thus learn the nature of the modifications, and can, as the case may be,

surmise or demonstrate their causes. It is evident that, without the genealogical lines which paleontology presents, it is impossible that our hypotheses on this subject can rest on any solid basis. With these lines completed, we will be able, on the other hand, ultimately to reach a demonstration in most if not all the cases which present.

In the first place, there has long been before the world a theory to account for these changes, and that is the doctrine of use and disuse, propounded by Lamarck. He believed that the use of a part of an animal caused it to grow larger, and that in consequence of disuse a part would grow smaller or become extinct. Another theory is frequently spoken of, as though it accounted for the origin of changes, and that is the Natural Selection of Darwin. While naturalists are generally agreed as to the importance of this principle in modifying the results of the creative energy, but few of them regard it as explaining in any way the *origin* of the changes with which it deals. In the very nature of things, "selection" can not act until alternatives have been presented. And Mr. Darwin and others, who treat of natural selection as though it were a cause of new structures, always premise by admitting that "there is in organic beings a natural tendency to variation." It is in accounting for this variation that the Lamarckian hypothesis is useful, and probably expresses a great law of organic nature. In the same way most of those who write of the "influence of the environment" (which Lamarck, by-the-way, fully considered), as though it embraced the causes of evolution, forget that the energy which impresses an animal from this source could have no effect unless the animal possess some impressibility or capacity for response. And they also often forget that an animal capable of free movement is able to modify its environment very materially.

There is one element of weakness in the Lamarckian theory of use. This is that use implies the presence of something to use, or the existence of a usable part or organ. It is thus incompetent to explain the *origin* of such a part *ab initio*, although it may account for the details of its structure, as its segmentation, branching, etc. So I have added to use the energy of *effort*, and the Lamarckian theory, completed, can be characterized as the theory of the origin of species, by *effort, use, and disuse.* A prominent cause of change of structure may be here referred to; and that is, change in consequence of excess or diminution of growth-energy, due to the action of use and effort in disturbing its equilibrium. That is to say, that excessive growth in one place has caused diminished growth in another, and *vice versa.* This derivative hypothesis explains the origin of many structures which are not useful to the possessor, and of others which appear to be positively injurious. Such characters can not, of course, be accounted for by the direct action of effort and use, which are necessarily directed toward beneficial ends. There are also numerous characters, chiefly of an ornamental nature, as color, etc., which are the direct result of the

physical impress of the environment, as temperature, light, humidity, movements of the medium, etc., which are only influenced by the animal as it places itself, by its movements, within or without the range of their influence. In spite of these facts, I believe the movements and habits of animals to lie at the foundation of their principal characters, and that the superstructure, be it due to whatever cause it may, rests upon that foundation. It will now be well to take a look at the evidence in favor of or against these theories, as presented by the science of vertebrate paleontology. A few examples will suffice.

In the first place, I will select an illustration of the effects of use on the articulations of the limbs and feet of the mammalia. I take first the ankle- and wrist-joints. In the ruminating animals (ox, deer, camel, etc.) and in the horse, among other living species, the ankle-joint is a very strong one, and yet admits of an extensive bending of the foot on the leg. It is a treble tongue-and-groove-joint; that is, two keels of the first bone of the foot, the astragalus, fit into two grooves of the lower bone of the leg, the tibia, while between these grooves a keel of the tibia descends to fill a corresponding groove of the astragalus. Such a joint as this can be broken by force, but it cannot be dislocated. Now, in all bones the external walls are composed of dense material, while the centers are spongy and comparatively soft. The first bone of the foot (astragalus) is narrower, from side to side, than the tibia which rests upon it. Hence the edges of the dense side-walls of the astragalus fall within the edges of the dense side-walls of the tibia, and they appear to have pressed into the more yielding material that forms the end of the bone, and pushed it upward, thus allowing the side-walls of the tibia to embrace the side-walls of the astragalus. Now, this is exactly what would happen if two pieces of similar dead material, similarly placed, should be subjected to a continual pounding in the direction of their length for a long period of time. And we can not ascribe any other immediate origin to it in the living material; but the probability of such origin is more probable in such substance, because of the perpetual waste and repair which are going on, and because of

FIG. 1.—HIND-FOOT OF CORYPHODON ELEPHANTOPUS, showing flat astragalus for ankle-joint. (From Eocene bed of New Mexico.) One half natural size.

the wonderful power which we so often see in growth, in repairing damages, and in providing for new conditions in cases of accidents. This inclusion of the astragalus in the tibia does not occur in the reptiles, but appears first in the mammalia, which descended from them.

The same active cause that produced the two grooves of the lower end of the leg produced the groove of the middle of the upper end of the astragalus. Here we have the yielding lower end of the tibia resting on the equally spongy material of the middle of the astragalus. There is here no question of the hard material cutting into soft, but simply the result of continuous concussion. The consequence of concussion would be to cause the yielding faces of the bones to bend downward in the direction of gravity. If they were flat at first they would begin to hollow downward, and a tongue above and groove below would be the result. And that is exactly what has happened. Without exception, every line of mammalia commenced with types with an astragalus which is flat in the transverse direction, or without median groove. From early tertiary times to the present day, we can trace the gradual development of this groove in all the lines which have acquired it. The upper surface becomes first a little concave; the concavity gradually becomes deeper, and finally forms a well-marked groove.

The history of the wrist-joint is similar. The surface of the fore-arm bones which joins the fore-foot is in the early tertiary mammalia uniformly concave. In the ruminating mammals it is divided into three fossæ, which are separated by sharp keels. These fossæ correspond with the three bones which form the first row of the carpus or palm. The keels correspond to the sutures between them. The process has been evidently similar to that which has been described above as producing the side-grooves in the end of the tibia. The dense walls of the sides of the three bones impinging endwise on the broad yielding surface of the fore-arm (radius) have gradually, under the influence of countless blows, impressed themselves into the latter. On the contrary, the surface above the weaker lines between the bones not having been subject to the impact of the blows, and influenced by gravity, remains to fill the grooves, and to form the keels which we observe.

There is another striking instance of the same kind in the feet of mammalia; that is, in the development of the keels and grooves which appear at the articulation of the first set of bones of the toes (metapodials) with the bones of the second set (phalanges). These keels first appear on the posterior side of the end of the first set of bones, projecting from between two tendons. These tendons, in many mammals, contain two small bones, one on each side, which act like the knee-pan, and resemble it in miniature, which are called sesamoid bones. These tendons and bones exercise a constant pressure on each side of the middle line, when the animal is running or walking, and

this pressure, together with the concussion with the ground, appears to have permitted the protrusion of the middle line in the form of a keel, while the lateral parts have been supported and even compressed. The reptilian ancestors of the mammals do not possess these keels.

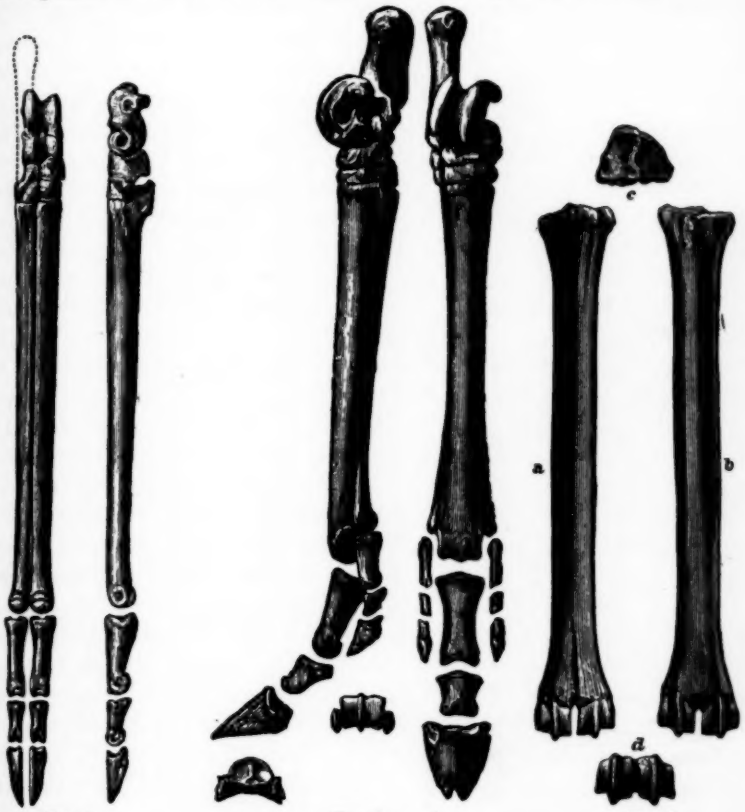


FIG. 2. FIG. 3. FIG. 4.

FIG. 2.—HIND-FOOT OF PRIMITIVE CAMELOID POEBROTHERIUM LABIATUM, showing grooved astragalus and first toe-bones without keel in front at lower end. (From Colorado.)

FIG. 3.—HIND-FOOT OF THREE-TOED HORSE (*Protohippus sejunctus*) (from Colorado), showing grooved astragalus, and trace of keel on front of lower end of first bone of middle toe.

FIG. 4.—UNITED FIRST BONES OF TWO MIDDLE TOES OF DEER-ANTELOPE (*Cosoryx furcatus*), showing extrusion of keel on front of lower end. (From Miocene of Nebraska.)

Now, the lines of mammalian descent displayed by paleontology are characterized, among other things, in most instances, by the gradual elevation of the heel above the ground, so that the animal walks on its toes. It is evident that in this case the concussion of running is applied more directly on the ends of the bones of the foot than is the case where the foot is horizontal. As a consequence we find the keel is developed farther forward in such animals. But in many of these, as the carnivora, the hippopotamus, and the camels, there is developed under the toes a soft cushion, which greatly reduces this concussion. In these species the keel makes no further progress. In other lines,

as those of the horse, the pig, and of the ruminants, the ends of the toes are applied to the ground, and are covered with larger hoofs, which surround the toe, and the cushion is nearly or quite dispensed with. These animals are especially distinguished by the fact that their metapodial keels extend entirely round the end of the bone, dividing the front, as well as the end and back, into two parts. This structure would seem to be a result of the greater force of the impact resulting from use of the legs, experienced by the end and front of the bone, which receives the blows.

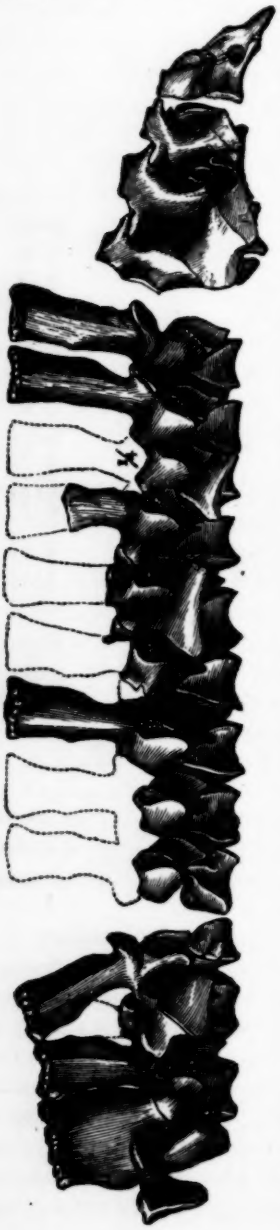


FIG. 5.—PART OF VERTEBRAL COLUMN OF THE FOSSIL BATRACHIAN *Eryops megacephalus*, one fourth natural size, showing segmentation, the left side.

I cite one more instance of the effect of use on the structure of the skeleton, and this time from the vertebral column. In a certain order of *Batrachia* from the Permian formation (the *Rhachitomi*), the bodies of the vertebræ are curiously segmented. Instead of a solid slightly modified from a cylinder, as in most vertebrates, we have three pieces. One of these is of nearly the form of a segment cut from an apple or orange having a crescentic outline and wedge-shaped section. The sharp edge is concave and is directed upward. On one side of each of the horns of this crescent a rhombic piece is applied, which, widening upward, supports the separate arch of the vertebra. These three pieces when together leave a central vacancy, which becomes, when all the vertebræ are placed end to end, a canal or tube. This was occupied by what is known as the chorda dorsalis, which is the central axis of the body of the simplest vertebrates, and is present in the early embryonic stages of all. In the growth of a reptile or mammal this flexible chorda is replaced by the bony vertebral bodies. The osseous material appears in the membranous sheath which covers it, and, gradually encroaching on it, first cuts it into segments and then fills it entirely. In the rhachitomous batrachia this process is not completed, as the chorda remains more or

less entire; and the ossification of its sheath and substance is laid down in the three segments already described.

The two segments visible from one side of the column form two wedges with their apices together, and their bases one up and the other down. Now, if a person who wears a coat of rather thick material will examine the folds of his sleeve as they are produced on the inner side of his arm, he will see a figure nearly like that of the segments of the vertebral column described. The folds will correspond to the sutures, and the interspaces to the bony segments. He will find that the spaces are lens-shaped, or, when viewed in profile, wedge-shaped, with the apices together. This arrangement results from the necessary mechanics of flexure to one side. In flexure of a cylinder like the sleeve, or like a vertebral column, the shortest curve is along the line of the greatest convexity of the cylinder. Here is the closest folding of the sheath, and here, consequently, the lines of fold in soft material, or fracture in hard material, will converge and come together. That is just what they do in both the sleeve and the rhachitomous vertebral column, the only difference being that in the animal

FIG. 6.—THE FOLDS ON THE INNER SIDE OF A COAT-SLEEVE, which correspond with the lines separating the segments of the vertebræ of the Eryops. The letter *i* is the basal segment or intercentrum; the *p* corresponds with the lateral segment, the pleurocentrum; and *n* represents the basal part at the upper or neural arch, which rests on *p* and *i*.

it is exhibited on both sides, and on the sleeve on only one side. This difference is, of course, due to the fact that the animal can bend himself in both directions, while the arm only bends in one direction.

It results from the above observations that the structure of the rhachitomous vertebral column *has been produced by the movements of the body from side to side, as in swimming, during the process of the deposit of mineral material* in and around the chorda dorsalis.* Here we have another convincing proof that use and effort have produced animal structure.

Instances like the above can be cited from many departments of zoölogy wherever paleontology has pointed out the lines of descent. I will not cite them further, but will draw some conclusions which are necessary and which are of general interest.

It is evident that use and effort imply some kind of movement on the part of the animal which puts them forth. Hence I have called

* This subject is more fully treated of in the "American Naturalist" for January, 1884.

the theory which holds that the structures of animals are the results of their movements the theory of kinetogenesis (from *kineo*, I move, and *genesis*). This theory is supported not only by the class of facts which I have adduced, but by another large class of a different kind, which demonstrate the alternative proposition, viz., that disuse is followed by loss and extinction of parts. This may be inferred from the very degenerate character of most animal parasites taken in connection with their embryology. The absence of limbs, of segments, of sense-organs, and even of more important vital organs observed in various parasites, is very remarkable. It is equally remarkable that the history of the development of such animals shows that in their earlier stages they are not parasitic, and possess many organs which are wanting in the adult. This brief history, condensed into the life of each individual parasite, no doubt, as in all growth-history, merely repeats that of the species as a whole. It teaches us that the ancestors were active, independent swimmers or fliers, as the case may have been, and that by the adoption of parasitic habits they ceased to use the many parts, which consequently dwindled and disappeared. This conclusion is sustained by paleontology wherever evidence can be obtained from that source. This is most evident in the history of the reptiles. Many forms of lizards of the present period are known to display curious defects. Such are the absence of some or all of the toes; of some or all of the limbs; of the eyelids; of the dermal folds about the eyes; and, finally, of the eyes themselves. Paleontology shows that these are not ancient or primitive types which survived, but that they are modern. Now, nearly all such lizards have habits which involve the least possible use of the limbs and of the sense of sight; they are subterranean, and many of them inhabit ants' nests and devour those insects for food. It is evident that here is a kind of parasitism, and its consequences are of the most marked character.

The nature of animal movements may now claim our attention. These, we know, are referred to two general divisions, the automatic and the voluntary. The popular definition of these classes of movements is that, in the latter case, choice or preference, and therefore will, is supposed to be exercised, and that in the former there is no such quality displayed. The automatic movements are called mechanical, and may be performed unconsciously, as the movements of the heart and digestive system, etc. Rigorously, however, the so-called voluntary acts do not proceed from any freedom or will proper on the part of an animal. They appear to do so, because they display intelligence of a higher order than the automatic acts, although it is true that intelligent design is not wanting from the latter either. Moreover, the so-called voluntary acts may be unconsciously performed, and the automatic may be consciously performed, as in the winking of the eyes and breathing, when attention is directed to them. So, then, the classification into conscious and unconscious is quite independent of that

into voluntary and automatic. As the term voluntary is misleading, the word ratiocinative has been substituted for it.

The relations of animal acts may, then, be considered as follows: Automatic acts display design for the well-being of the animal, but are invariable in their action, not changing immediately in adaptation to new or modified needs. Ratiocinative acts, on the other hand, are performed in accordance with circumstances as they arise, and are not rhythmical or invariable in their action. Their existence implies the presence of a certain development of mind, which the automatic acts do not so obviously display. Ratiocinative acts are very common in animals, as those who observe them can always testify. The automatic acts increase in relative importance as we descend the scale of being, but as they also display a general beneficial design it is not possible to draw the line between them and the ratiocinative. In fact, the one passes into the other by the well-known process which I call cryptonoÿ, as will presently be explained. If acts affect structure, it is evident, that if the acts are beneficial, the structure they produce must be so also. From what has preceded, it is also evident that the more intelligent acts will produce correspondingly more beneficial structures than the less intelligent. But since these changes are only effected by long-continued movements on the part of an animal, it is clear that an act is likely to become automatic before it can become an important cause of evolution of animal forms. The history of animal movements has probably been as follows:

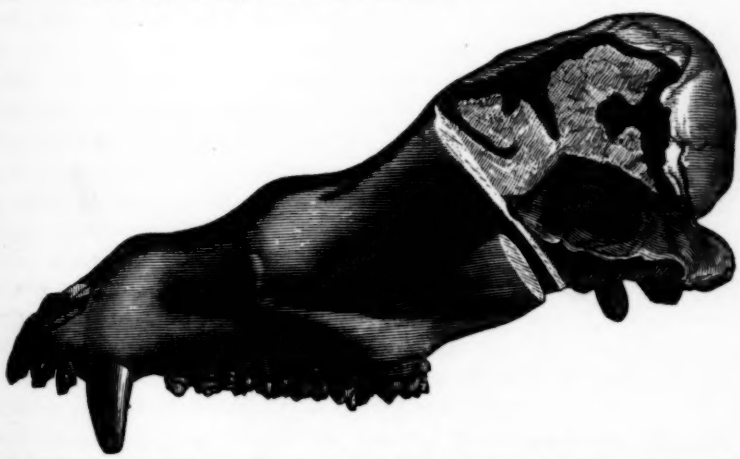


FIG. 7.—SKULL OF CORYPHODON ELEPHANTOPUS, two ninths natural size; a corner removed from the skull so as to display the small brain-cavity at the base. (From New Mexico.)

Protoplasm presents certain movements, of which contractility is one, which will respond to certain stimuli under proper conditions of nutrition and temperature. It may perform movements which cause a simple mass of it to change its location in a fluid medium. Such acts, however, lack the element of design, or adaptation to the needs of the

animal, whether they be constant or temporary ones. In order to display this property it is necessary that sensation should exist, and that this should be pleasurable or painful, in order to produce a determinate movement to increase the one or escape the other. This is the basis of all design, for without consciousness there can be no design. Just where this consciousness first displays or displayed itself in living things it is not possible to know at present with certainty, but its first exhibition was probably in the pain of hunger. The first designed act was, then, the taking of food. The first structure was, therefore, also some kind of arrangement for seizing and surrounding food. This having been performed, another set of functions had its birth, one which was destined to follow all new experiences, and in turn to dominate all later acts. This is the memory of the act and of its consequences, which remains as the basis of mind. An impress once made on consciousness is not lost, because it has modified the molecular structure of some part of the living material in a way as yet unknown to us. The movement which results from this memory is the first designed act, and this also affects structure, and produces the first motor link between mind and body, as the first stimulus perceived produced the first sensory link. From this time onward the law of use and effort has its way. Its first result is to build a mind-machine, or nervous system, or its equivalent. This kind of building has evidently preceded all others in time, and its latest and highest product is the human brain. The evidence of vertebrate paleontology places this statement beyond the stage of mere hypothesis. We have learned that, with a few minor exceptions, the brains of the vertebrata, and especially of the mammalia, have greatly increased in complexity and in size with the lapse of geological time. This is illustrated by the accompanying figures of the brain-chambers or casts of brain-chambers of two ancient and one late Tertiary mammals. The *Coryphodon elephantopus* is the largest animal of the three, and the *Phenacodus primævus*, of which the skeleton was figured in the preceding article, is a little smaller than the *Proçamelus occidentalis*, the third species. The last is the latest species in time, and is one of the ancestors of the existing camels and llamas. The much greater size and complexity of the brain, and especially of the cerebral hemispheres, as compared with the two other species, are striking.

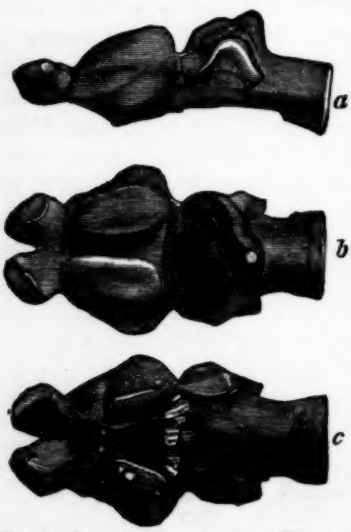


FIG. 8.—CAST OF BRAIN-CAVITY OF PHENACODUS PRIMÆVUS, showing small hemispheres: *a*, side; *b*, from above; *c*, from below. One half natural size. (From Wyoming.)

We have now the beginning of an explanation of the element of design in the movements of animals. But, first, the explanation is necessary to account for the long-continued automatic acts which have changed the hard and apparently fixed structures of so many of the higher forms of life.

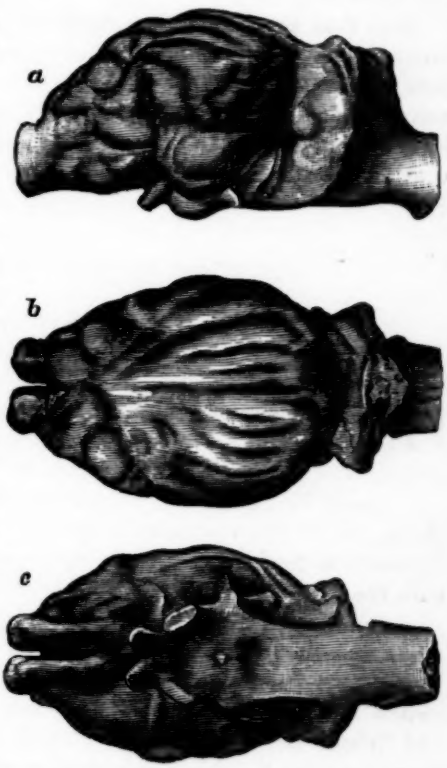


FIG. 9.—CAST OF BRAIN-CAVITY OF POCAMELUS OCCIDENTALIS, one half natural size: *a*, profile; *b*, above; *c*, below. (From New Mexico.)

Automatic and unconscious ratiocinative acts are the product of conscious ratiocinative acts by the process of cryptonoÿ already referred to. This process is one of the most wonderful which the field of science presents to our contemplation. It is simply this: that when a brain, or other organ of consciousness, has once acquired an habitual movement, consciousness disappears from that act, and it enters the unconscious and generally automatic stage. This demonstrates two things: First, that consciousness is not necessary to a designed act which has become a habit, no matter how complicated that habit may be; second, *that consciousness does reside in matter which has not acquired habits, and which therefore does not yet possess the structure which makes such habits possible.*

We now have a true theory of the influence of the environment on an animal. Sensation being understood, the animal proceeds to adapt itself to its surroundings by the adoption of appropriate habits, from which appropriate structures arise. Without such response on the part of the animal, the greater part of the world would have remained uninhabited by all but the lowest forms of life, and these too might have been extinguished. From the simplest temporary methods of defense and protection, animals have developed the habits of laying up stores, of building houses, of the arts of the chase, of migrations over wide territories. There can be no doubt that the constant exercise of the mind in self-support and protection has developed the most wonderful of all machines, the human brain, whose function is the most

wonderful of phenomena, the *human** mind. And the acts of other parts of the organism, which have been the outcome of this process, have produced the varied structures which to-day constitute the animal kingdom.

It is thus shown to a demonstration, by means of the principle of kinetogenesis, that evolution is essentially a process of mind. The source of the consciousness, which is back of it, is at present an unsolved problem. That it has existed and does exist, there can be no question, and there is no sufficient reason for supposing that it will not continue to exist.

"THE METAPHYSICAL SOCIETY."

A REMINISCENCE.

By R. H. HUTTON.

[IN the autumn of 1868 Mr. Tennyson and the Rev. Charles Pritchard—Savilian Professor of Astronomy—were guests together in my house.

A good deal of talk arose on speculative subjects, especially theology, and in the course of it the idea was suggested of founding a Theological Society, to discuss such questions after the manner and with the freedom of an ordinary scientific society.

I volunteered to endeavor to bring such a body together if Mr. Tennyson and Mr. Pritchard would promise to belong to it, and I then consulted other friends, beginning with Dean Stanley, Dean Alford, Archbishop Manning, the Rev. James Martineau, the Bishop of Gloucester and Bristol, Dr. Ward of the "Dublin Review," Mr. R. H. Hutton of the "Spectator," and one or two more, finding them all willing to join. I next went to "the opposition," and, explaining our plan, found Professor Huxley, Professor Tyndall, Mr. Froude, Mr. Walter Bagehot, Sir John Lubbock, and others, equally ready to co-operate.

The originally intended name of Theological Society was dropped in favor of "Metaphysical Society," under which full discussion of the largest range of topics from all points of view could be better insured, and on the 21st of April, 1869, we held our first meeting at Willis's Rooms.

I remember Mr. Froude—who was among our first members—saying that, if we hung together for twelve months, it would be one of the most remarkable facts in history. But we "hung together" for nearly twelve years, meeting once a month, usually at an hotel, where, after dining together, a paper was read by some member, and afterward discussed. Mr. Tennyson's remark at an early meeting seemed

* The word *human* is emphasized because it is not yet proven that protoplasm is the only possible physical basis of mind.

always borne in mind—that "modern science ought, at any rate, to have taught us one thing—how to separate light from heat."

When the list of members and the character of the subjects discussed are considered, many will agree that it is matter for congratulation, and a pleasant sign of the times, that such a society should have lived its full life in London in entire harmony. It came to an end because, after twelve years of debating, there seemed little to be said which had not already been repeated more than once. The members were as follows:

Mr. Tennyson.
Mr. Gladstone.
The Duke of Argyll.
Dean Stanley.
Archbishop Manning.
The Bishop of St. David's.
The Archbishop of York.
Prof. Huxley.
The Bishop of Peterborough.
Prof. Tyndall.
Mr. Frederic Harrison.
Lord Selborne.
Prof. Clifford.
Father Dalgairns.
Sir James Stephen.
Dr. Ward.
The Bishop of Gloucester and Bristol.
Dean Alford.
The Dean of St. Paul's.
Mr. Ruskin.
Mr. Froude.
Mr. Grant Duff.
Mr. Robert Lowe.
Rev. Prof. Maurice.
Rev. Prof. Pritchard.
Prof. Robertson.
Sir Alexander Grant.
Lord Arthur Russell.
Rev. Canon Barry.
Rev. James Martineau.
Prof. Seeley.
Mr. Walter Bagehot.
Sir John Lubbock.
Rev. Mark Pattison.
Dr. Carpenter.
Prof. Lushington.
Mr. Shadworth Hodgson.
Dr. Andrew Clark.
Mr. Leslie Stephen.
Mr. John Morley.
Sir William Gull.
Dr. Gasquet.
Prof. Fraser.
Mr. George Grove.
Rev. Dr. Mozley.
Mr. James Hinton.
Prof. Sylvester.
Dr. Bucknill.
Prof. St. George Mivart.
Prof. Barnes Upton.
Mr. Henry Sidgwick.
Mr. R. H. Hutton.
Rev. Robert Clarke.
Mr. W. R. Greg.
Mr. Matthew Boulton.
Mr. Frederick Pollock.
Dr. Acland.
Hon. Roden Noel.
Mr. James Knowles.

Among our chairmen—appointed annually, but sometimes serving for two years successively—were Sir John Lubbock, Cardinal Manning, Professor Huxley, Mr. Gladstone, Dr. Ward, Dr. Martineau, Lord Selborne, and Lord Arthur Russell.

The character of the subjects brought forward may be gathered from the titles of some of the papers, and, as the discussions were ab-

solutely confidential and unreported, they were almost always of much animation and interest. They suggested to myself (as honorary secretary to the society) the idea of the "Modern Symposium" which several times appeared in this Review. The following were among the papers read before the society:

The Theory of Causation.
The Theory of a Soul.
Is God unknowable?
What is Death?
Will and Responsibility.
The Scientific Basis of Morals.
The Nature and Authority of Miracle.
Has a Frog a Soul?
On the words Nature, Natural, and Supernatural.
The Ethics of Belief.
What is Matter?
The Soul before and after Death.
What is a Lie?
How do we come by our Knowledge?
The Personality of God.
The Verification of Beliefs.
The Emotion of Conviction.
Memory as an Intuitive Faculty.
The Relation of Will to Thought.
Matter and Force.
The Absolute.
The Nature of Things in Themselves.
The Nature of the Moral Principle.
The Evidence of the Miracle of the Resurrection.
The Arguments for a Future Life.
Hospitals for Incurables from a Moral Point of View.
Double Truth.

The subjoined article, kindly volunteered by Mr. Hutton, was suggested by him, not as a portrait of any actual meeting, but as a reminiscence of the sort of debate which used to go on. Its faithfulness is remarkable, except for the omission of his own valuable part in the discussion.—EDITOR *Nineteenth Century.*]

THE following attempt to give an impression of a typical meeting of the once rather famous "Metaphysical Society," of which I was throughout a member, must not be regarded as in any sense containing an historical report of an individual debate. No such reports were, so far as I know, ever taken. But to a rather diligent member of the society there were plenty of opportunities of learning the general views of the more eminent members on such a subject as was discussed at the meeting here selected for treatment; and though it is likely

enough that none of them, except of course Dr. Ward, whose paper was really read (though he may have made no final reply), spoke on this particular occasion, as I have imputed to them; and though several of those to whom I have attributed remarks may not have been present at this particular discussion at all, yet I do not think I shall be found to have misrepresented any of their views.* If I have, the responsibility and fault are mine.

At the meeting of the Metaphysical Society which was held on the 10th of December, 1872, Dr. Ward was to read a paper on the question, "Can experience prove the uniformity of Nature?" "Middlemarch" had been completed and published a few days previously. On the day following the meeting the Convocation of Oxford was to vote upon the question raised by Mr. Burgon and Dean Goulburn, whether the Dean of Westminster (then Dr. Stanley) should be excluded for his heresies from the List of Select Preachers at Oxford or not. The "Claimant" was still starring it in the provinces in the interval between his first trial and his second. Thus the dinner itself was lively, though several of the more distinguished members did not enter till the hour for reading the paper had arrived. One might have heard Professor Huxley flashing out a skeptical defense of the use of the Bible in board-schools at one end of the table, Mr. Fitzjames Stephen's deep bass remarks on the Claimant's adroit use of his committal for perjury, at another, and an eager discussion of the various merits of Lydgate and Rosamond at a third. "Ideal Ward," as he used to be called, from the work on the "Ideal of a Christian Church," for which he had lost his degree nearly thirty years earlier at Oxford, was chuckling with a little malicious satisfaction over the floundering of the orthodox clergy, in their attempts to express safely their dislike of Dean Stanley's latitudinarianism, without bringing the Establishment about their ears. He thought we might as well expect the uniformity of Nature to be disproved by the efforts of spiritualists to turn a table, as the flood of latitudinarian thought to be arrested by Mr. Burgon's and Dean Goulburn's attempt to exclude the Dean of Westminster from the List of Select Preachers at Oxford. Father Dalgairns, one of Dr. Newman's immediate followers, who left the English Church and entered the Oratory of St. Philip Neri with him, a man of singular sweetness and openness of character, with something of a French type of playfulness in his expression, discoursed to me eloquently on the noble ethical character of George Eliot's novels, and the penetrating disbelief in all but human excellence by which they are pervaded. Implicitly he intended to convey to me, I thought, that

* Whenever those views were actually given in the words here used, though occurring in the reading of other papers, I have always placed them in inverted commas. Whenever no inverted commas are used the words and thoughts are mine, though I believe them to represent faithfully the views of the speakers to whom they are attributed.—R. H. H.

nowhere but in the Roman Church could you find any real breakwater against an incredulity which could survive even the aspirations of so noble a nature as hers. And as I listened to this eloquent exposition with one ear, the sound of Professor Tyndall's eloquent Irish voice, descanting on the proposal for a "prayer-gauge," which had lately been made in the "Contemporary Review," by testing the efficacy of prayer on a selected hospital ward, captivated the other. Everything alike spoke of the extraordinary fermentation of opinion in the society around us. Moral and intellectual "yeast" was as hard at work multiplying its fungoid forms in the men who met at that table as even in the period of the Renaissance itself.

I was very much struck then, and frequently afterward, by the marked difference between the expression of the Roman Catholic members of our society and all the others. No men could be more different among themselves than Dr. Ward and Father Dalgairns and Archbishop Manning, all of them converts to the Roman Church. But, nevertheless, all had upon them that curious stamp of definite spiritual authority which I have never noticed on any faces but those of Roman Catholics, and of Roman Catholics who have passed through a pretty long period of subjection to the authority they acknowledge. In the Metaphysical Society itself there was every type of spiritual and moral expression. The wistful and sanguine, I had almost said hectic idealism, of James Hinton struck me much more than anything he contrived to convey by his remarks. The noble and steadfast but somewhat melancholy faith which seemed to be sculptured on Dr. Martineau's massive brow, shaded off into wistfulness in the glance of his eyes. Professor Huxley, who always had a definite standard for every question which he regarded as discussable at all, yet made you feel that his slender definite creed in no respect represented the cravings of his large nature. Professor Tyndall's eloquent addresses frequently culminated with some pathetic indication of the mystery which to him surrounded the moral life. Mr. Fitzjames Stephen's gigantic force, expended generally in some work of iconoclasm, always gave me the impression that he was revenging himself on what he could not believe, for the disappointment he had felt in not being able to retain the beliefs of his youth. But in the countenances of our Roman Catholic members there was no wistfulness—rather an expression which I might almost describe as a blending of grateful humility with involuntary satiety—genuine humility, genuine thankfulness for the authority on which they anchored themselves; but something also of a feeling of the redundance of that authority, and of the redundance of those provisions for their spiritual life of which almost all our other members seemed to feel that they had but a bare and scanty pasturage.

Dr. Ward, who was to read the paper of the evening, struck me as one of our most unique members. His mind was, to his own apprehension at least, all strong lights and dark shadows. Either he was

absolutely, indefensibly, "superabundantly" certain, or he knew no more "than a baby," to use his favorite simile, about the subjects I conversed with him upon. On the criticism of the New Testament, for instance, he always maintained that he knew no more than a baby, though really he knew a good deal about it. On the questions arising out of Papal bulls he would often say that he was as absolutely and superabundantly certain as he was of his own existence. Then he was a very decided humorist. He looked like a country squire, and in the Isle of Wight was, I believe, generally called "Squeer Ward"; but, if you talked to him about horses or land, he would look at you as if you were talking in an unknown language, and would describe, in most extravagant and humorous terms, his many rides in search of health, and the profound fear with which, whenever the animal showed the least sign of spirit, he would cry out, "Take me off! take me off!" He was one of the very best and most active members of our society, as long as his health lasted—most friendly to everybody, though full of amazement at the depth to which skepticism had undermined the creed of many among us. A more candid man I never knew. He never ignored a difficulty, and never attempted to express an indistinct idea. His metaphysics were as sharp cut as crystals. He never seemed to see the half-lights of a question at all. There was no penumbra in his mind; or, at least, what he could not grasp clearly, he treated as if he could not apprehend at all.

When dinner was over and the cloth removed, a waiter entered with sheets of foolscap and pens for each of the members, of which very little use was made. The ascetic Archbishop of Westminster, every nerve in his face expressive of some vivid feeling, entered, and was quickly followed by Dr. Martineau. Then came Mr. Hinton, glancing round the room with a modest half-humorous furtiveness, as he seated himself among us. Then Dr. Ward began his paper. He asked how mere experience could prove a universal truth without examining in detail every plausibly asserted exception to that truth, and disproving the reality of the exception. He asked whether those who believe most fervently in the uniformity of Nature ever show the slightest anxiety to examine asserted exceptions. He imagined, he said, that what impresses physicists is the fruitfulness of inductive science, with the reasonable inference that inductive science could not be the fruitful field of discovery it is, unless it rested on a legitimate basis, which basis could be no other than a principle of uniformity. Dr. Ward answered that the belief in genuine exceptions to the law of uniform phenomenal antecedents and consequents does not in the least degree invalidate this assumption of the general uniformity of Nature, if these exceptions are announced, as in the case of miracles they always must be, as demonstrating the interposition of some spiritual power which is not phenomenal, between the antecedent and its natural consequent —which interposition it is that alone interrupts the order of phenome-

nal antecedence and consequence. "Suppose," he said, that "every Englishman, by invoking St. Thomas of Canterbury, could put his hand into the fire without injury. Why, the very fact, that in order to avoid injury he must invoke the saint's name, would ever keep fresh and firm in his mind the conviction that fire does naturally burn. He would therefore as unquestioningly in all his physical researches assume this to be the natural property of fire as though God had never wrought a miracle at all. In fact, from the very circumstances of the case, it is always one of the most indubitable laws of Nature which a miracle overrides, and those who wish most to magnify the miracle are led by that very fact to dwell with special urgency on the otherwise universal prevalence of the law." There was a short pause when Dr. Ward had concluded his paper, which was soon ended by Professor Huxley, who broke off short in a very graphic sketch he had been making on his sheet of foolscap as he listened.

Dr. Ward, said Professor Huxley, had told us with perfect truth that the uniformity of Nature was only held, by even the most thoroughgoing of clear-minded physicists, as a fruitful working hypothesis, the assumption of which had led to a vast number of discoveries, which could not have been effected without it. If they could not assume that under heat the vapor of water would expand one day as it had expanded the previous day, no locomotive would be of any use; if they could not assume that under certain given conditions the majority of seeds put into the ground would spring up and reproduce similar seed, no fields would be sown and no harvest would be reaped. In innumerable cases where the same antecedents had apparently not been followed by the same consequents, thinking men had taken for granted that they must have been mistaken in supposing the antecedents to be the same, and had found that they were right, and that the difference in the antecedents had really been followed by the difference in the consequents. He, for his part, should not object at all to examine into any presumptive case of miracle sufficiently strong to prove that in a substantial number of cases Englishmen had been enabled to thrust their hands into the fire without injury, by adopting so simple a safeguard as calling on St. Thomas of Canterbury. But the truth was, that asserted miracles were too sparse and rare, and too uniformly accompanied by indications of either gross credulity or bad faith, to furnish an investigator jealous of his time, and not able to waste his strength on futile inquiries, with a sufficient basis for investigation. Men of science were too busy in their fruitful vocation to hunt up the true explanation of cases of arrested miracle, complicated as they generally were with all sorts of violent prepossessions and confusing emotions. He, for his part, did not pretend that the physical uniformity of Nature could be absolutely proved. He was content to know that his "working hypothesis" had been proved to be invaluable by the test of innumerable discoveries, which could never have

been made had not that working hypothesis been assumed. Indeed, what evidence has any man even for the existence of his own home and family, better than that of a fruitful hypothesis, which has time after time resulted in the expected verification? No man can be absolutely certain that the home he left an hour ago is standing where it did, or that the family he left in it are still in life; still, if he acts on the hypothesis that they are there, he will, in innumerable cases, be rewarded for making that assumption, by finding his expectations verified, and in but a very few cases indeed be disappointed.

If, then, Dr. Ward asks, said Professor Huxley, whether or not I hold that experience can, in a mathematical sense, *prove* the uniformity of Nature, I answer that I do *not* believe it; that I believe only that, in the assumption of that uniformity of Nature, we have a working hypothesis of the most potent kind, which I have never found to fail me. But further, if I might use the word "believe" loosely, though with much less looseness than that with which men who are not students of science habitually use it, I should not hesitate to avow a belief that the uniformity of Nature *is* proved by experience, for I should be only too glad to think that half the "demonstrated" beliefs of metaphysicians are even a tenth part as trustworthy as the great working hypothesis of science. The man of science, however, "who commits himself to even one statement which turns out to be devoid of good foundation, loses somewhat of his reputation among his fellows, and if he is guilty of the same error often he loses not only his intellectual but his moral standing among them; for it is justly felt that errors of this kind have their root rather in the moral than in the intellectual nature." That, I suppose, is the reason why men of science are so chary of investigating the trustworthiness of the *soi-disant* miracles to which Dr. Ward is so anxious that we should pay an attention much greater than any which in my opinion they deserve. For the scientific man justly fears that, if he investigates them thoroughly, he shall wound many amiable men's hearts, and that if he does not wound amiable men's hearts he shall compromise his own character as a man of science.

As Professor Huxley's rich and resonant voice died away, Father Dalgairns, after looking modestly round to see whether any one else desired to speak, began in tones of great sweetness: Professor Huxley has implied that to the scientific student the words "I believe" have a stricter and more binding force than they have to us theologians. If it really be so, it is very much to our shame, for no words can be conceived which are to us more solemn and more charged with moral obligation. But I confess that the drift of Professor Huxley's remarks hardly bore out to my mind the burden of his peroration. It seems that "a working hypothesis" is the modest phrase which represents even the very maximum of scientific belief, for would Professor Huxley admit that he has any belief, except of course

one resting on an immediately present consciousness, deeper than his belief in the uniformity of Nature? I suppose not. Now, theologians are accustomed to assert, and I think with justice, that it is impossible to entertain any belief—whether it be only a working hypothesis or something more—in the uniformity of Nature, without basing it on the irrefragable trustworthiness of the human faculties. In one of our earliest discussions Dr. Ward proved his case that on the irrefragable trustworthiness of memory, for example, for all facts which it positively asserts, rests the whole structure of human knowledge; and this in a sense much deeper than any such expression as "working hypothesis" will express. Without assuming this irrefragable trustworthiness, Dr. Ward has reminded us that I could not now know that I am replying to Professor Huxley at all, or indeed who I myself am, or who is Professor Huxley. Without absolutely assuming the trustworthiness of memory, how should I have the least glimmering of a conception of that expressive personality from whose mouth the weighty utterances we have just heard proceeded? Yet if you grant me the trustworthiness of memory, when it speaks positively of a recent experience, can you deny me the trustworthiness of other human faculties equally fundamental? Is my "belief" in the distinction between right and wrong, between holiness and sin, any less trustworthy than my belief in the asseverations of my memory? Did not Professor Huxley himself suggest in his closing remarks that the *moral* roots of our nature strike deeper than the intellectual roots; in other words, that if memory be much more than a "working hypothesis," if its trustworthiness be the *condition* without which no working hypothesis would be even possible, there are moral conditions of our nature quite as fundamental as even the trustworthiness of memory itself? I hold it, I confess, most irrational to have an absolute and undoubting belief in the uniformity of Nature based on any accumulation of experience, for no such accumulation of experience is possible at all without an absolute and undoubting belief in the past, and this no merely present experience can possibly give us. And I hold such a belief in the uniformity of Nature, based on anything but the trustworthiness of our faculties, to be irrational, for precisely the same kind of reason for which I hold it to be irrational to question the belief in God. The solemnity which Professor Huxley attaches to the words "I believe," I attach to them also. Moreover, I could not use them in their fullest sense of anything which I regard merely as a "working hypothesis," however fruitful. But I deny that we theologians regard our deepest creed as a working hypothesis at all. We accept the words "I believe in God," as we accept the words "I believe in the absolute attestations of memory," as simply forced upon us by a higher intuition than any inductive law can engender. When I say "I believe in God," I use the word believe just as I use it when I say "I believe in moral obligation," and

when I say "I believe in moral obligation," I use the word believe just as I do when I say "I believe in the attestations of memory." "God is not necessary only to my conception of morality. His existence is necessary to the existence of obligation." I know God by "a combination of intuition and experience, which is Kant's condition of knowledge. If there be a God, our imagination would present him to us as inflicting pain on the violator of his law, and lo! the imagination turns out to be an experienced fact. The Unknowable suddenly stabs me to the heart." I believe in the uniformity of Nature only in the sense in which I believe in every other high probability—for instance, only in the sense in which I believe that the sun will rise to-morrow. I believe in God in the sense in which I believe in pain and pleasure, in space and time, in right and wrong, in myself, in that which curbs me, governs me, besets me behind and before, and lays its hand upon me. The uniformity of Nature, though a very useful working hypothesis, is, as Professor Huxley admits, unproved and unprovable as a final truth of reason. But "if I do not know God, then I know nothing whatsoever," for if "the pillared pavement is rottenness," then surely also is "earth's base built on stubble."

There was a certain perceptible reluctance to follow Father Dalgairns, which lasted some couple of minutes. Then we heard a deep-toned, musical voice, which dwelt with slow emphasis on the most important words of each sentence, and which gave a singular force to the irony with which the speaker's expressions of belief were freely mingled. It was Mr. Ruskin. "The question," he said, "Can experience prove the uniformity of Nature? is, in my mind, so assuredly answerable with the negative which the writer appeared to desire, that precisely on that ground the performance of any so-called miracles whatever would be really unimpressive to me. If a second Joshua to-morrow commanded the sun to stand still, and it obeyed him, and he therefore claimed deference as a miracle-worker, I am afraid I should answer: 'What! a miracle that the sun stands still? —not at all. I was always expecting it would. The only wonder to me was its going on.' But even assuming the demonstrable uniformity of the laws or customs of Nature which are known to us, it remains to me a difficult question what measure of interference with such law or custom we might logically hold miraculous, and what, on the contrary, we should treat only as proof of the existence of some other law hitherto undiscovered. For instance, there is a case authenticated by the signatures of several leading physicians in Paris, in which a peasant-girl, under certain conditions of morbid excitement, was able to move objects at some distance from her without touching them. Taking the evidence for what it may be worth, the discovery of such a faculty would only, I suppose, justify us in concluding that some new vital energy was developing itself under the conditions of modern life, and not that any interfer-

ence with the laws of Nature had taken place. Yet the generally obstinate refusal of men of science to receive any verbal witness of such facts is a proof that they believe them contrary to a code of law which is more or less complete in their experience, and altogether complete in their conception; and I think it is therefore the province of some one of our scientific members to lay down for us the true principle by which we may distinguish the miraculous violation of a known law from the natural discovery of an unknown one. . . . However," he proceeded, "the two main facts we have to deal with are that the historical record of miracle is always of inconstant power, and that our own actual energies are inconstant almost in exact proportion to their worthiness. First, I say the history of miracle is of inconstant power. St. Paul raises Eutychus from death, and his garments effect miraculous cure, yet he leaves Trophimus sick at Miletus, recognizes only the mercy of God in the recovery of Epaphroditus, and, like any uninspired physician, recommends Timothy wine for his infirmities. And in the second place, our own energies are inconstant almost in proportion to their nobleness. We breathe with regularity, and can count upon the strength necessary for common tasks, but the record of our best work and our happiest moments is always one of success which we did not expect, and of enthusiasm which we could not prolong."

As Mr. Ruskin ceased, Walter Bagehot, the then editor of the "Economist," and a favorite among us for his literary brilliance, opened his wide black eyes, and, gulping down what seemed to be an inclination to laugh at some recollection of his own, said: Mr. Ruskin's remark that he had always been expecting the sun to stand still was to me peculiarly interesting, because, as I have formerly told the society, whatever may be the grounds for assuming the uniformity of Nature, I hold that there is nothing which the natural mind of man, unless subjected to a very serious discipline for the express purpose of producing that belief, is less likely to assume. A year or two ago I ventured to express in this room the opinion that credulity is the *natural* condition of almost every man. "Every child," I said, "believes what the footman tells it, what the nurse tells it, and what its mother tells it, and probably every one's memory will carry him back to the horrid mass of miscellaneous confusion which he acquired by believing all he heard." I hold that children believe in the suggestions of their imaginations quite as confidently as they believe in the asseverations of their memories; and if grown-up men do not, it is only that their credulity has been battered out of them by the hard discipline of constant disappointment. What can be better evidence that there is at least no *a priori* belief in the uniformity of Nature than the delight in fairy tales, which, certainly in childhood, are accepted with quite as much private belief that some great enchanter's wand will be triumphantly found at last, as are the dullest and most matter-of-fact of histories? Indeed, you will find in almost every young person of any

promise the profoundest tendency to revolt against the law of uniform succession as too dull to be credible, and to exult in the occasional evidence which the history of their time affords that "truth after all is stranger than fiction." Is not the early love of tales of marvel, and the later love of tales of wild adventure and hair-breadth escapes, and again, the deep pleasure which we all feel in that "poetic justice" which is so rare in actual experience, a sufficient proof that men retain, even to the last, a keen prepossession against the doctrine that laws of uniform antecedency and consequence can be traced throughout the most interesting phases of human life? Even in the city, where so many hopes are crushed every day, the "Bull" goes on believing in his own too sanguine expectations, and the "Bear" in his own dismal predictions, without correcting his own bias as experience should have led him to correct it. I believe it will be found that nothing is more difficult than to beat into the majority of minds the belief that there is such a thing as a "law of Nature" at all. So far as I can judge, nine women out of ten have never adequately realized what a law of Nature means, nor is the proportion much smaller for men, unless they have been well drilled in some department of physics. Of course, I heartily agree with Dr. Ward that experience can not *prove* the uniformity of Nature, and for this very good reason, among others, that it is impossible to say what the uniformity of Nature means. We can not exhaust the number of interfering causes which may break that uniformity. I at least can not doubt that, so far as mind influences matter, there may be a vast multitude of real disturbing causes introduced by mind to break through those laws of uniformity in material things, of which at present we know only the elements. But of this I am very sure, that at present we are much apter to accept superficial and inadequate evidence of the breach of laws of uniformity than we ought to be; that education does not do half enough to beat out of our minds that credulous expectation that there is some disposition in the governing principles of the universe, either to favor us or to persecute us, as the case may be, which springs, not from experience, but from groundless prejudice and prepossession; and that much greater efforts should be made to set before young people the true inexorability of Nature's laws than is actually made at present. It is quite true that no man can say positively either that the sun will rise to-morrow, or that an iron bar will fall to the ground if the hand drops it. We do not absolutely *know* that the sun may not blaze up and go out before to-morrow, as it is said that some stars of considerable magnitude have blazed up and gone out. We do not know that there may not be some enormously powerful and invisible magnet in the neighborhood which will attract the iron bar upward with more force than that with which the earth pulls it downward. But we do know that in millions and billions of cases expectations founded on the same sort of evidence as the expectation that the sun will rise to-morrow, and that the dropped

bar will fall to the earth, have been verified, and that the imaginative illusion which half-educated people still so often indulge, that exceptions will occur for the occurrence of which there is no rational evidence, is a most mischievous one, which we ought to try to eradicate. We ought to engage what I have ventured in this society to call the "emotion of conviction," the caprices of which are so extravagant and so dangerous, much more seriously on the side of the uniformity of Nature than we have ever hitherto done. We should all try to distinguish more carefully than we do between possibility, probability, and certainty. It is not as certain that the sun will rise to-morrow as it is that I was cold before I entered this room; it is not as certain that Messrs. Baring's acceptances will be paid as it is that the sun will rise to-morrow; it is not as certain that Peel's Act will always be suspended in a panic as it is that Messrs. Baring's acceptances will be paid. And it is difficult for "such creatures as we are" to accommodate our expectations to these varying degrees of reasonable evidence. But though experience, however long and cumulative, can never prove the absolute uniformity of Nature, it surely ought to train us to bring our expectations into something like consistency with the uniformity of Nature. And as I endeavor to effect this in my own mind, I certainly can not agree with Mr. Ruskin that I have always been "expecting" the sun to stand still. Probably as a child I was always expecting things quite as improbable as that. But if I expected them now I should not have profited as much by the disillusionizing character of my experience as I endeavor to hope that I actually have.

There was a general smile as Bagehot ceased, but the smile ceased as Mr. Fitzjames Stephen—the present Sir James Stephen—took up the discussion by remarking, in the mighty bass that always exerted a sort of physical authority over us, that while the society seemed to be pretty well agreed upon the main question, namely, that the uniformity of Nature could not be absolutely proved by experience, or, indeed, by any other method, there was a point in Dr. Ward's paper, namely, the challenge to examine seriously into the authenticity of miracles, which had not been dealt with. For my part, he said, I am quite ready to examine into the evidence of any so-called miracle, that is, into the evidence of any unusual event which is offered to prove Divine interference in our affairs, when it comes before me with sufficient presumption of authority to render it worth my while to investigate it; though I probably should not agree with Dr. Ward as to what constitutes such a presumption. Certainly "a bare, uncorroborated assertion by a person professing to be an eye-witness of an event is not sufficient evidence of that event to warrant action of an important kind based upon the supposition of its occurrence. When you are obliged to guess, such an assertion may be a reason for making one guess rather than another. Less evidence than this would make a banker hesitate as to a

person's credit, or would lead a customer to doubt whether his banker was solvent; but in such cases all that is possible is a guess more or less judicious, and a guess, however judicious, is a totally different thing from settled rational belief. As regards all detailed matters of fact, I think there is a time, greater or less, during which the evidence connected with them may be collected, examined, and recorded. If this is done, a judgment can be formed on the truth of allegations respecting them at any distance of time. Such judgments are rarely absolute; they ought always or nearly always to be tempered by some degree of doubt, but I do not think they need be affected by lapse of time. If, however, this opportunity is lost, if no complete examination is made at the time of an incident, or if being made it is not properly or fully recorded, clouds of darkness which can never be dispelled settle down upon it almost immediately. All that remains behind is an indistinct outline which can never be filled up. Under certain conditions rare occurrences are quite as probable as common ones. The main condition of the probability of such an event is that the rare occurrence should, from its nature and from the circumstances under which it occurs, be capable of being observed, and that the evidence of it should be recorded in the manner which I have already described. If a moa were caught alive and publicly exhibited for money, or if the body of a sea-serpent were to be cut up upon the coast and duly examined by competent naturalists, the existence of moas and sea-serpents could be proved beyond all reasonable doubt. The reason why their existence is disbelieved or doubted is not that they are seen, if at all, so seldom, but because in each particular instance they are seen, if at all, in such an unsatisfactory way that it is doubtful whether they ever were seen. There are innumerable ghost-stories in circulation, but as far as I know no instance has ever yet been even alleged to exist in which the existence of a ghost has been properly authenticated as readily and as conclusively as that of any other being whatever. Stories of the interference of unseen agents stand upon exactly the same footing, speaking generally. Isolated instances occur in all ages and countries, but the common characteristic of them all is to be unauthenticated. Ten cases distinctly proved under the conditions referred to . . . would do more to settle the question of the existence of miracles as a class than innumerable cases depending on assertions which were not properly examined when they were originally made, and which can now never be examined. On the other hand, what reason can possibly be suggested why the action of an invisible person upon matter should not be ascertained just as clearly as the action of a visible person? The restoration of a dead body to life might, if it occurred, be proved as conclusively and as notoriously as the death of a living person, or the birth of a child. If such events formed a real class to which new occurrences might be assigned, a large number of instances of those occurrences would be, so to speak, upon record, established beyond all

doubt, and the very existence of the controversy shows that nothing of the sort exists."

Hereupon the Archbishop of Westminster, looking at Mr. Stephen with a benign smile, said: Mr. Stephen's investigations into the evidence of the interference of unseen agents in human affairs are hardly on a par with some of those undertaken by the Church to which I belong. In canonizing, or even beatifying those who are lost to us, the Holy See has long been accustomed to go into the evidence of such events as those to which Mr. Stephen has just referred, and that with a disposition to pick holes in the evidence, which, if he will allow me to say so, could hardly be surpassed even by so able a sifter of evidence as Mr. Stephen himself. Nor is it indeed necessary to go into the archives of these laborious and most skeptically conducted investigations. If there were but that predisposition among Protestants to believe in the evidence of the unseen which Dr. Ward desired to see, there would, I am convinced, be many believers in miracles of the most astounding kind, and of miracles that have happened in our own time, many within the last year. Let those who choose, for instance, look into the evidence of the most astonishing cure of varicose veins which took place only last year in the south of France—a malady of thirty years' standing, and of steady progress throughout that time, attested on the positive evidence of French physicians, who had themselves repeatedly seen and prescribed for the patient. Yet they admitted that all they could do would be at most to alleviate his sufferings by the application of mechanical pressure—and they nevertheless declared the cure to have been effected in a single night, the only new condition having been the believing application of the Lourdes water to the body of the sufferer. Here is a case where all Mr. Fitzjames Stephen's conditions are satisfied to the full. I do not, however, apprehend that Mr. Stephen will sift the evidence, or even regard it as worth his serious attention. He has hardly assigned sufficient force to that strong predisposition to incredulity which is so widely spread at this moment in the Protestant world, a predisposition which I can not entirely reconcile with Mr. Bagehot's very striking remarks on the universal credulousness of the natural man. Perhaps, however, there may be such credulousness where there is no prejudice, and yet incredulity still more marked where there is. I have been a careful observer of the attitude of Protestants in relation to the controversy between the natural and supernatural. I have seen its growth. I have watched its development. I am persuaded that Mr. Stephen is quite wrong in supposing that the matter can be settled as one of evidence alone. You must first overcome that violent prejudice in your minds which prevents you from vouchsafing even a glance at the evidence we should have to offer you. But I will, if the society permits me, leave that part of the subject, and return to the principal question before us—the impossibility of proving the uniformity of Nature from

experience alone. Now, how do we Catholics, who have a philosophy the value of which we imagine that you believers in Spencer and Mill and Bain greatly underrate, account for the uniformity of Nature without trenching in any way on the supernatural basis of that Nature? I will show you. Aquinas says in his "Summa"—and the Archbishop, of course, pronounced his Latin in the Continental manner—"Tota irrationalis natura comparatur ad Deum sicut instrumentum ad agens principale"—the whole of inanimate and irrational Nature bears to the Divine being the relation of an instrument to the principal agent. That is to say, the Divine intellect conceives the law which the Divine will sanctions and enforces by a great methodical instrument. The *natura naturans* makes use of the *natura naturata*. The law determines the instrument it is to use, and the instrument it is to use determines the world. Why, then, should the law be regular and not variable? Why, because it is the instrument of a being who is not variable. The schoolmen tell us that Nature has an appetite, a desire to accomplish its ends. They say of Nature "appetit," "desiderat." Such are the phrases they use. And as no constant aim, no true development can be attained by capricious, inconsistent, inconsequent action, by instruments incoherent, part with part—for the gratification of Nature's appetite, for the fulfillment of her desire, and the attainment of her purpose, a constancy and fixity of method are essential which are never interrupted, save where the Divine power modifies the instrument for its own good purpose. Thus the uniformity of Nature is based upon the wisdom of God, and the wisdom of God is manifested in the uniformity of Nature. St. Thomas has said, "Proprium est naturæ rationalis ut tendat in finem quasi se agens et ducens ad finem." And again: "Necessitas naturalis inhærens rebus, quâ determinantur ad unum, est impressio quædam Dei dirigentis ad finem, sicut necessitas quâ sagitta agitur ut ad certum signum tendat, est impressio sagittantis et non sagittæ"; that is, the necessity, or may we not say the uniformity of Nature, is a career impressed upon it by the Divine archer, who never misses his mark; it is not the arrow which determines that career, but the archer who points and who dismisses the arrow in its flight. But St. Thomas goes on: "Sed in hoc differt, quod id quod creaturæ a Deo recipiunt est earum natura, quod autem ab homine rebus naturalibus imprimitur præter earum naturam ad violentiam pertinet." Dr. Ward will correct me if I am wrong, but I interpret this as meaning that if what men ingraft on lower creatures is spoken of by the angelic doctor as doing them a certain violence, altering, I suppose, their mere involuntary qualities by infecting them with a certain human purposiveness not their own, how much more is it evidently open to the Divine purpose to ingraft on this uniformity of Nature a supernatural bent of its own, to open it, as it were, to the power of miracle, to infuse it with the significance of revelation!

Dr. Ward, I thought, winced a little when this appeal was made to him; whether it was that he differed with the Archbishop as to the drift of the passage quoted, or whether he regarded the society as in general too little educated in philosophy to appreciate arguments derived from the teaching of St. Thomas. As the Archbishop ceased, a good many eyes were turned upon Dr. Martineau, as if we had now got into a region where no less weighty a thinker would be adequate to the occasion.

I think, said Dr. Martineau—speaking with a singularly perfect elocution, and giving to all his consonants that distinct sound which is so rare in conversational speech—I think that the course of this discussion has as yet hardly done justice to the *a priori* elements in human thought which have contributed to the discovery of the general uniformity of Nature, and to the axiomatic character of the principle which we are discussing. I should not entirely agree with the Archbishop or with St. Thomas if I rightly apprehended the quotations from him, that we ought to ground our belief on the uniformity of Nature *primarily* on our belief in the constancy of the Divine mind. Historically, I doubt whether that could be maintained. For example, the Hebrew Scriptures, which are full of the praise of the moral constancy of the Creator, appear to attach very little importance to the uniformity of Nature's methods, which they often treat as if they were as pliant as language itself to the formative thought behind it. Still less can I agree with Mr. Bagehot's view that everything which rushes into the mind is believed without hesitation till hard experience scourges us into skepticism. I should say rather that the understanding is prepared to accept uniform laws of causation by the very character of human reason itself. It is remarkable enough that Aristotle fully recognizes the close connection between the necessary character of human inference and the necessary relation of cause with effect, that he treats the "beginning of change" (ἀρχὴ κινήσεως) as either the cause which necessarily results in an effect, or the reason which necessarily results in an inference. "An efficient cause, therefore, may be found in any beginning of change either in the physical world or the logical. In both cases it has the same characteristics: *necessity*, whether in the form of inevitable sequence or in that of irresistible inference; and *consecutive advance*, a step at a time, along a determinate line, whether in outward nature or in inward thought. Whatever is, it either acts out or thinks out what is *next*. So far, therefore, as the universe is at the disposal of efficient causes, its condition at each moment results purely from the immediately prior, without the possibility of any new beginning. If an experienced observer could compress into a formula the law of all the simultaneous conditions, he would be able to foresee the contents of any future moment—not, however, to modify them, for his prescience depends on their being in themselves determinate, and on his calculations em-

bracing all the elements of the problem, including the states of his own mind. This efficient causality can be denied by no one who admits the dynamic idea at all; and no phenomenon can dispense with it."

Here we have, as I conceive, the clew to the principle of the uniformity of Nature. So far as Nature is purely dynamic, and so far as force is measured by reason, we can not stray from the rigid logic of fact and the equally rigid logic of thought. Doubtless it will be replied that, as in the mind of man there is a free spring of force, which is as yet undetermined, which is potential and not actual force, so there is behind Nature a free spring of force which is as yet undetermined, which is potential and not actual nature—in short, a power above nature and capable of modifying it; in other words, supernatural. And that doctrine I should heartily accept. The uniformity of Nature is the uniformity of force, just as the uniformity of reasoning is the uniformity of thought. But just as the indeterminateness of creative will stands behind the determinateness of the orbit of force, so the indeterminateness of creative purpose stands behind the determinateness of the orbit of thought or inference. I hold that man is not wholly immersed in dynamic laws, that though our physical constitution is subject to them, our mental constitution rises above them into a world where free self-determination is possible. I do not wonder, therefore, that we find it difficult to realize the rigidity of the laws of efficient causation even so far as it would be good for us to realize them. But I can not think that any one who has once contracted the habit of even fixing his own attention can doubt for a moment that cause and effect are connected together by efficient links, nor that, if force outside us means the same thing as force inside us, the relation of cause and effect is as necessary—unless some higher power interfere to modify the cause—as the relation of premises to conclusion. With regard to Dr. Ward's invitation to us to examine more carefully the credentials of miracle, I am inclined to agree with Mr. Stephen that, if there were any tangible number of incontrovertible miracles, there could be no controversy on the question whether or not such things can be. But then I should not apply that remark to any case of internal consciousness of supernatural influence, because, from the very circumstances of the case, the evidence of the existence of such influence can not be open to any mind except that which is the subject of it, and in my view it is quite unreasonable to deny that there are indirect but yet conclusive proofs in history that such supernatural influences have transformed, and do still habitually transform, the characters of the very greatest of our race. But it is one thing to see the evidence of spiritual influence in every page of human history and quite another to attach importance to such preternatural occurrences as the Archbishop has recently referred to, which are usually so mixed up with superstitions of all kinds, and so great a variety

of hysterical emotions, that I for one should despair of any good result from investigating minutely these curious conquests effected by pretentious physical marvels over the gaping intellectual credulity of moral coldness and disbelief.

Here the general discussion ended, but Dr. Ward, who had the right of reply, exercised it with alertness and vigor.

I can not understand, he said, Dr. Martineau's position, that because the best testimony which we have in modern times to the interference of Divine power in the chain of physical causation is more or less mixed up with what he would regard as superstition and hysterical emotion, therefore it is perfectly justifiable to leave such matters uninvestigated, and to pass by on the other side. Surely the whole character of modern civilization would be altered if we could prove satisfactorily for ordinary minds that the Divine will is a true cause, which manifests itself habitually to those who humbly receive the Divine revelations. Is not Dr. Newman's celebrated assertion that England would be in a far more hopeful condition if it were far more superstitious, more bigoted, more disposed to quail beneath the stings of conscience, and to do penance for its sins, than it is, at least plausible for one who, like Dr. Martineau, believes profoundly that the true worship of a righteous will is the highest end of all human life? Can anything be more superabundantly evident, more conspicuously and, so to say, oppressively clear, than that ninety-nine men out of every hundred live as if God were at most nothing more than a remote probability, which it is hardly worth while to take into account in the ordinary routine of life? Suppose, if you please, that the majority of men by studying the Lourdes miracles will be brought, if they are convinced at all, to burn an immense number of wax tapers to the holy Virgin, and to dress up a number of very gaudy dolls in the churches dedicated to her, by way of showing their gratitude to her for curing paralytics and other miserable sufferers by the application of Lourdes water. Is that so much more superstitious, after all, than attributing similar cures to the transit of St. Peter's shadow, or to handkerchiefs taken from St. Paul's body, as the author of the Acts of the Apostles certainly did? Nor, indeed, is it a matter of the very highest moment whether people show their faith foolishly or whether it overshoots the mark, and attributes imaginary effects to a real cause. What is a matter of the highest moment is whether or not they feel or do not feel their religious faith in every action of their life. If God is really ruling you, is it not better to feel his eye upon you, even though you show your sense of that vigilance unreasonably and foolishly, than to live on very much as you would do, if, as Isaiah said, God were on a journey or had gone to sleep? Can any one deny that any awakening, however rude its consequences, to the reality of Divine power, would be infinitely better than the rapidly growing habit of living as if behind Nature there were no God? I do not of course say this to

any member of our society who doubts the reality of God's government, but only to those who, with Dr. Martineau, regard it as the very first of all truths. But to them I say, if miracles still exist, if they still exist in the very form in which they are said to have existed in the Acts of the Apostles, if they can be attested by men of science themselves, if, in any Church, they happen not merely every year, but in considerable numbers every year, and admit of all the tests to which Mr. Stephen has referred us, then surely it can be nothing but a most reprehensible and guilty fastidiousness to give the go-by to the evidence of these things, simply on the ground that they are mixed up with a great deal of vulgar taste and of hysterical feeling. Is it not better to have a vulgar belief in God than to have a fine susceptibility to scientific methods? Is it not better to have a feverish longing to do his will than to have a delicate distaste for morbid devotion? The uniformity of Nature is the veil behind which, in these latter days, God is hidden from us. I believe in the uniformity of Nature, but I believe in it far more fervently as the background on which miracle is displayed than I do merely as the fertile instrument of scientific discovery and of physical amelioration.—*Nineteenth Century.*

A STUDY OF RECENT EARTHQUAKES.

By M. A. DAUBRÉE.

SINCE communication between the extremities of the earth has become both easy and rapid, our ideas on many subjects have been modified and have become more precise. Facts that formerly appeared singular and extraordinary are recognized as frequent and habitual. This is the case with reference to earthquakes. Numerous telegrams, a few months ago, told in every part of the civilized world of the shocks from which Andalusia, in Spain, was suffering. To the astonishment and lively curiosity which these phenomena excited was added a deep emotion which disasters of so dramatic and painful a character would cause. The interest in the study of these things is also enhanced by the additional knowledge it gives us respecting the constitution of the crust of the earth—knowledge which, constantly increasing, enables us the better to comprehend the different parts of the mechanism of these subterranean perturbations.

Among the more recent earthquakes was the one that destroyed most of the Island of Scio. On the 3d of April, 1881, about an hour and forty minutes after noon, the city of Scio and thirty or forty villages in the southern part of the island were disturbed with a violent trepidation. The shaken and cracked houses were still standing, when, a few minutes afterward, a second shock, equally violent, came

on, and finished the work of the first. With it five thousand persons were buried under the rubbish. A little while afterward four thousand other persons were killed. Hardly had the people recovered from the terror of one shock, than others came on, causing general panic and stupor. Hardly a quarter of an hour would pass without a new shock, and the wounded who had succeeded in extricating themselves from the rubbish were buried in it again. "Death," said an eye-witness, "seemed to pursue its victims with fury. In less than an hour Scio was an utter ruin." The agitations of the ground continued, with only short interruptions, for a year. During 1879 and 1880 Scio had suffered from frequent tremors, sometimes repeated as many as ten times in a day. Mitylene and Smyrna were also similarly affected, but none of the shocks were strong enough to cause great anxiety. They were, as it were, the subterranean preparation for the catastrophe that was to burst out a few months afterward.

The disaster that desolated the Island of Ischia two years afterward excited no less of emotion. The main shock, on the 28th of July, 1883, was accompanied by a fearful rumbling, which was estimated to last about twenty seconds. There was an extremely violent upward movement that broke up the houses, followed by an undulatory pulsation. The points most disturbed were aligned along the two deep fractures of strata that traverse the island at right angles to one another, crossing nearly under Casamicciola.

Less than a month after the shocks at Ischia followed the terrific explosion of the volcanic Island of Krakatoa, near Java, with all its unparalleled accompaniments: the planting of a deep sea where had been a mountain; the prodigious masses of pumice and stones from the volcanic throat causing intense darkness for hours at long distances; the finer particles scattering in the atmosphere and disturbing its transparency and causing the red lights for months; the marine waves propagated to the ends of the ocean with the speed of the tides; the aërial waves making the circuit of the globe, according to barometrical registrations, in two opposite directions; the thirty thousand human beings that perished; and the villages and cultivated lands which it blotted out—all caused a most vivid impression in all civilized lands.

Now it is Andalusia, one of the finest parts of Europe, that is struck with disasters. The shock that was felt on the 22d of December, 1884, on the western coasts of Spain and Portugal, and as far as the Azores and Madeira, seemed to be a forerunner of the one, of incomparably greater intensity, that took place three days afterward in another part of the Iberian Peninsula. At about nine o'clock in the evening of the 25th of December, the southern part of Andalusia was so roughly shaken that fifty-six towns and villages in the provinces of Malaga and Granada were devastated in less than ten seconds; and twenty of these places were nearly entirely destroyed. Among

them were Alhama, Arenas el Rey, Albunuelas, Periana, Zaffaraya, and Venta de Zaffaraya. These places, situated above the center of the agitation, are scattered over a surface of which the principal dimension does not reach forty miles; but the movements of the ground extended far beyond this region, to Seville on the west, Cape Gadez on the east, and Molena de Aragon. The movements provoked phenomena of different kinds. Crevasses, several miles long and several yards wide, were opened at various places. From one of them, near Santa Cruz, exhaled fetid gases, having the odor of sulphureted hydrogen, and there burst from the same fissure a copious spring of sulphurous water with a temperature of about 90°; while at a short distance from this point the thermal springs of Alhama, that have been in use from antiquity, were heated to a higher temperature and acquired a sulphurous character.

The districts near the Sierra Nevada and its ramifying spurs have frequently been the center of subterranean commotions; and it is an important fact, not to be neglected, that the shocks have many times, as in the present case, been repeated for several weeks in succession.

Among the movements which the ground undergoes during earthquakes, vertical shocks of great energy may sometimes be felt. During the earthquake in Calabria in 1783, houses were thrown up into the air, as if by the explosion of a mine; and at Riobamba, in Colombia, in 1812, several persons were cast bodily upon a hill more than three hundred feet high. These motions are called *succussions*, or subsultory tremors. The most frequent movements, and generally the most extended, are the undulatory ones, which are propagated horizontally, like the waves which we can observe at any time on a liquid surface. Like those waves, they may, when continued for some minutes, cause a kind of sea-sickness. Sometimes the terrestrial undulations are so strong as to bend over trees till their limbs touch the ground. These two forms of tremor may be associated together, or they may succeed one another at very short intervals. Various instruments — seismographs or seismometers, analyzers, and pendulums—are used to determine their intensity, direction, and duration, and register their characters.

The intensity of the shocks is extremely variable. Sometimes they are hardly perceptible, or marked only by low rumblings; often they are so strong that works of masonry are overthrown by them. For this reason special modes of construction are employed in countries subject to earthquakes, as adapted to oppose the least resistance.

In the most usual undulatory movement, the agitation is naturally stronger at the top of buildings than at their base. Thus, in the theatre at Madrid, on the 25th of December last, the upper gallery was visibly shaken, while the parquette was unmoved. For the same reason, the motions are incomparably less sensible in the interior of mines than on top of the ground. M. Domeyko relates that he was

once at the bottom of the silver-mines of Charnacillo, more than six hundred feet underground, during an earthquake that destroyed his own house and several others right above him, while he did not feel the least agitation.

The duration of the shocks is generally very brief, sometimes not more than a second or two. The undulatory movements are more prolonged. A few instants are sufficient to produce the most disastrous effects. Three shocks, each of which was estimated to be not more than four seconds long, destroyed more than 20,000 persons in and around Carácas in March, 1812; and the convulsion at Riobamba, in 1797, killed as suddenly 30,000 victims.

But, however overwhelming and disastrous in reference to our persons and buildings earthquakes may be, it must be borne in mind that the amplitude of their movements is wholly insignificant in proportion to the dimensions of the globe whose epidermis they shake. The phenomenon is rarely limited to a single shock. Generally, several shocks follow one upon another at short intervals. In many cases, the movements are repeated for months and years, with pauses of a variable duration, so as to form as a whole, till they are totally extinguished, what might be called a seismic period. After the shock which overthrew Thebes, on the 18th of August, 1851, the commotions continued in Bœotia for eleven months, occurring sometimes as often as three times in twenty-four hours. Long series of shocks disturbed a part of Scotland during the two years from the 20th of October, 1839, to the 7th of December, 1841. Hundreds of similar examples might be cited.

The chain of the Alps has furnished examples of seismic periods in many of its parts. Series of shocks were felt at Pignerol, in Piedmont, from the 2d of April, 1808, till the 17th of May following, during which time not a day passed but some movement was felt. Sometimes the tremors were noiseless, sometimes they were accompanied with commotions preceding the destruction of buildings. The commotions were renewed on the 26th of September, the 28th of October, and the 22d of November; and in the next year on the 13th of March and 26th of June. Similar periods of seismic action were observed in le Valais in 1755, on Lake Gardo in 1866, on Monte Baldo in 1868, and at Belluno in 1873. The present period in Andalusia is of the same kind. The prelude of the 23d of December, which disturbed a part of the Spanish Peninsula, the great earthquake of the 25th of December, and that long succession of shocks which still continued on the 9th of March with sufficient violence to cause new ruins, belong to the same series. As Humboldt has remarked, it is noteworthy that series of this kind are produced more especially in countries distant from volcanoes.

In the disturbed regions we may generally remark a tract of limited extent in which the movement is particularly energetic. It cor-

responds, without doubt, with the deep-seated center of impulsion, and has been called the epicenter. Here is where the vertical shocks or succussions are most usually felt. From these radiate the undulatory movements, the speed of propagation of which has been estimated at from 1,100 to 1,500 feet per second, or about that of sound in the air. Sometimes the area of disturbance is very limited, even when the convulsion is most violent; at other times it is very extensive, as was the case in the Lisbon earthquake of 1755, which affected a surface equivalent to one-thirteenth of that of the globe. Most frequently the linear dimensions of the agitated surfaces are included within from 65 to 600 miles, or from one four-hundredth to one fortieth of the circumference of the earth.

The area of disturbance is usually irregular in form, and not circular, as was once supposed. Sometimes it is much lengthened in one direction, following the lines of neighboring mountains or other important accidents of structure. During the earthquakes of 1783 and October, 1876, the chain of the Apennines served as a protecting wall to the eastern provinces of the Italian Peninsula. While one side of the chain was assailed by thousands of shocks, which caused great disasters, nothing whatever was felt on the opposite slope. In the Alps, most of the earthquakes take place in the lateral, north and south spurs, which are formed of sedimentary beds, while the central chain, composed of crystalline rocks, is not disturbed. The Andes of South America form a natural bulwark which the strongest convulsions of the Pacific littoral, while they extend a long distance parallel to the chain, hardly ever cross; and, if occasionally a few shocks are propagated beyond it, they become extremely weak.

The movements are very unequally perceptible within the area of disturbances; and between two points shaken by the same impulsion there may be intermediate points that continue quiet. These are sometimes called bridges or arches. The shocks are frequently accompanied by noises resembling heavily loaded wagons rolling over the pavement, or subterranean thunders or roarings; but their intensity bears no kind of proportion to that of the agitation. The great earthquake of Riobamba, in 1797, was silent. But the sounds have relation to the rocks that transmit them. Then there are subterranean rumblings that are associated with shocks like the *bramidos* of Guanajuato, in Mexico, in 1784, continuing for a month, under terror of which the inhabitants left the city. There were flashes as of lightning, alternating with long rollings, like that of distant thunder. This phenomenon gradually passed away. The noises associated with earthquakes seem to be of the same nature as those that accompany eruptions. The latter are propagated through the ground, not the air, for hundreds of miles. But nothing else that is known of this kind reaches the proportions of what took place on the 26th of August, 1883, at the eruption of Krakatoa, the sounds of which were heard within the whole

area of a circle of 30°, or nearly 2,000 miles radius, or a diameter of one sixth the circumference of the globe.

The ocean basins are also disturbed, as is proved by the shocks suffered by ships on the deep, without any apparent external cause, and which give an impression as though the vessel were running upon a shoal. The movements of the littoral, also, however slight may be their intensity, are transmitted to the liquid mass. The sea retires from the shore, leaving the bottom dry, sometimes for several miles. Then it returns swiftly upon itself, and, overleaping its normal limit, precipitates itself with fury, and as if in assault, toward the interior of the country, as an enormous wave, which has been frequently known, as in Chili, to reach a height of 100 or 125 feet. Then it retires, carrying out upon the deep whatever it has gathered up in its passage. This terrible oscillation is repeated three or four times with decreasing energy, unless the movements of the ground persist. These invasions of the sea, or tidal-waves, are often more dreaded by the people, who have had experience of them, than the shocks on land. The huge waves are also propagated in the ocean to a very great distance from the center of disturbance. Twelve hours after an earthquake that destroyed the city of Simoda, Japan, in December, 1854, a formidable wave was precipitated upon the Californian coast, 5,600 miles away. In 1868 a wave of similar origin destroyed Arequipa and Arica, Peru, and ingulfed 30,000 persons. It seemed to have come from Honolulu, in twelve hours, or with a speed of 450 miles an hour. The most striking example is that of the wave that followed the Krakatoa explosion, which traveled over a distance of 11,890 miles, or half-way round the globe, in twenty hours and fifty minutes, or at the rate, according to M. Bouquet de la Grye's estimate, of about 900 feet a second.

Earthquakes may also effect permanent changes in the relief of the land, not only in the shape of crevasses and the overturning of rocks; slight though appreciable elevations have also been observed, as in Chili, in 1822, 1835, and 1837. In the last case, marine shells, still alive and adhering to the rocks on which they had grown, appeared above the level of the sea, and served as indisputable witnesses of the change of level which had been suddenly produced.

Movements of another class are extremely weak, and can not be perceived without the aid of special and delicate instruments. In 1869 M. d'Abbadie, examining the surface of a mercurial bath in his observatory at Abbadia, discovered very slight but frequent variations in the situation of the vertical, from which he inferred that the ground is not always motionless, even when it has all the appearances of being so. The same fact has since been confirmed in many places. Abrupt oscillations that have been frequently perceived in the astronomical glasses at the observatory of Pulkowa, and were observed at Nice on the 27th of November, 1884, are also revelations of disturbances in

the terrestrial crust. The French Academicians Bouguer and La Condamine had already come to a similar conclusion in 1741, when they were measuring zenith distances of stars. It could hardly have been anticipated that the observation of the stars would reveal processes that were going on down in the interior of our planet.

These movements, not directly perceptible by our senses, are subjected to an attentive daily study in Italy, at twenty-eight stations, scattered from one end of the peninsula to the other; and the results of the observations are centralized at the geodynamic observatory in Rome under the direction of M. Rossi. The movements are distinguished as very rapid and prolonged tremors (*tremiti*), and microseismic undulations, characterized by their extreme slowness. The observations of each day are depicted on a map of Italy by means of conventional signs, so that they may be followed in all their details as well as in the aggregate, at a single glance. Weak as these phenomena may be, they are well worthy of attention by reason of their continuous and general character; for they reveal an internal labor under the foundations of the ground, that never stops.

The crust of the earth also suffers displacements of a secular slowness, unaccompanied by any sudden movement; a class of phenomena which would never have been made known, if the mean level of the sea did not offer, at the shore, an invariable beach-mark by which to measure them. Tracts, which have manifestly been submerged within historical times, are now above the level of the sea, and constitute what are called raised beaches; while, on the other hand, forests, described in history as partly submarine, are now, in consequence of the depression of the soil, wholly under water. Such changes of level, very numerous and well established in all parts of the globe, are sometimes repeated in an oscillatory fashion of alternate elevations and depressions. They were formerly attributed to changes in the level of the sea, but the movement is in the land. They are in continuance of analogous changes which took place on vast scales during all the ancient geological periods. They are not to be confounded with superficial erosions and delta formations, which are quite different in character as well as in cause.

In view of these facts we are justified in saying that the crust of the earth is very far from being still. At every instant and in many of its parts it is undergoing very pronounced and often violent shocks. More frequently the movements are simply thrills, which can be discovered and studied only by a kind of auscultation. They are really continuous and of different kinds. It remains to inquire to what subterranean causes they should be attributed.

Numerous as the observations on earthquakes may be, they concern merely the external manifestations of a phenomenon the source of which is completely hidden from us, separated by a considerable thickness of rocks. Hence we have no clear, certain data by which to sup-

port an explanatory hypothesis. The phenomena have been variously ascribed to subterranean electric storms, to the influence of the sun, supposed to be potent over the interior regimen of the planets as well as upon their course in their orbits; to thrusts of the liquid or semi-liquid masses of the interior against parts of the solid crusts, which may be caused by the same forces as produce the tides; to sudden reductions of atmospheric pressure; or to the fall of immense masses of rocks in vast interior cavities.

Numerous and exact studies, bringing into clear view the relations of earthquakes with the geological structure of the countries subject to them, have given us a better comprehension of their organic causes. An important fact, developed by patient statistical research, is the great inequality in the geographical distribution of the phenomena. There are vast regions in which they are very rare and feeble, and others where the agitations are frequent and often very violent. But it is a significant fact in this connection that the frequency of the disturbances is not so much associated with geographical position as with peculiar characters in the constitution of the crust of the earth. Thus, many earthquake regions are characterized by the presence of active volcanoes. A striking example of such association is presented in the narrow tract between the Andes and the Pacific Ocean, in South America, particularly in Colombia, Ecuador, and Chili. "On the coasts of Peru," says A. von Humboldt, "the sky is always clear; neither hail nor storms nor fierce lightnings are known; the subterranean thunder attending the earthquake-shocks takes the place of the thunder of the clouds. By long habit and the general opinion that only two or three destructive shocks are likely to occur in a hundred years, the people of Lima are but little more afraid of earthquakes than those of the temperate zones are of hail-storms." In this region, between the sixteenth and twenty-fourth degrees of latitude, there are eighteen volcanoes; Chili, eminently subject to earthquakes, has thirty-three active volcanoes, between 33° and 43° south. Very different conditions prevail east of the Cordilleras, where vast countries like Brazil have no earthquakes. Farther north, on the isthmus, there are regions where the shocks are so frequent that one of them has been called "Cuscuttan," or the hammock. The single state of Nicaragua has twenty-four volcanoes. Along the coast of Asia is a zone of volcanoes and earthquakes about 9,000 miles long. It begins at Barren Island in the Bay of Bengal, crosses Sumatra, Java, the Moluccas, and the Philippines, bends around by Formosa and the neighboring archipelagoes to Japan, and then to the Kurile Islands and Kamchatka, and ends at last in the Aleutian Islands. Through all this zone the volcanoes are numerous and active, and in some parts of it at least, as in Japan and the Philippine Islands, the earth is never at rest. The seismograph at Manila is always in motion, even when the ground seems still, and a year never passes without a severe shock. The connection

between earthquake crises and volcanic crises is also shown by alternations in their activity. Every volcanic eruption is heralded by precursory tremors, whose violence is calmed down as soon as a volcanic outlet is opened for the escape of the vapors. Now, the vapor of water is the recognized cause of volcanic eruptions, and constitutes, in all parts of the earth, the most abundant and most constant emanation from them. It is the agent that throws out from the depths to the surface the lavas, which, despite their high temperature, hold it incorporated in their paste ; in the same way that carbonic acid, dissolved in water, forces the liquid impetuously out of a mineral-water or a champagne bottle ; and it also shoots quantities of solid matter, stones, lapilli, and cinders, violently into the atmosphere. It is logical to believe that this vapor is likewise the cause of the agitations that accompany volcanic crises. Agreeably to this idea, Kircher and Humboldt regarded volcanoes as safety-valves against earthquakes.

Other countries, again, where there are no volcanoes, are disturbed with no less energy and frequency, and that over great areas. Of such is the southern part of the basin of the Mediterranean. Syria with Palestine, Asia Minor, Turkey in Europe, Greece and the archipelagoes, Italy, Sicily, the southern part of the Iberian Peninsula, and a part of its western coast around Lisbon, have shown evidences of this predisposition within historical times. In each of these countries are districts or places that have been associated with most disastrous convulsions. In them we may discern a common and essential characteristic in the shape of a dislocation of the constituent strata, which is revealed for the most part in a mountainous relief.

In some whole countries the sedimentary strata, which form a notable part of the thickness of the earth's crust, have remained horizontal or nearly so, as they were deposited. In other countries, and over considerable areas, the corresponding strata are raised up, bent, and contorted in different ways, having been subjected to dislocations through enormous thicknesses. Such lifts and foldings can not have taken place in solid masses without being accompanied by many and important fractures. The principal classes of such fractures, which are nearly vertical, are called faults. They crop out and cut the surface of the ground, sometimes for tens and hundreds of miles, and are of indefinite depth, or descend to below where it is possible for man to penetrate ; whenever a fault is produced, the two sides are displaced, and must rub hard upon one another ; and vast rocky surfaces are thus engraved, striated, and polished : thence they are called mirrors in the language of the miners.

The occurrence of these facts is not confined to mountain-chains, but may be observed in countries that are marked by only slight prominences, but which have undergone similar actions through all their constituent strata. It is evident that the solid envelope of the globe has undergone dislocations at many epochs in its history. The

manifestations of gigantic force thus plainly registered are the effects of ancient back-foldings and of lateral or horizontal pressures. It is as if the crust of the earth had become too large for the supporting nucleus, and had, to keep in contact with it, to shrink up and bend upon itself. These foldings and fractures have given origin to chains of mountains.

Now, the geological study of earthquakes has shown that their centers of impulsion are in relation with the ground-lines of fracture and dislocation. The disturbed bands are usually longitudinally parallel to the chains. A recent example of this linear disposition has been added in the latest earthquake in Andalusia, the major axis of which, according to M. Fouqué, is parallel to the mountain-crests of the province, as well as to the numerous faults that cut it up. Another important point to be noticed is that the countries in which the mountains have most recently acquired their latest relief are the ones in which these subterranean agitations are particularly frequent.

The Andalusian masses which have been so rudely disturbed within a few months partake of all the structural conditions that have just been noticed. The Sierra Nevada is among the youngest chains of mountains on the globe. The tertiary strata around it have been powerfully lifted up, sometimes to more than three thousand feet above the sea, without having their horizontality destroyed. According to M. de Botella there are also, in different places at the foot of the chain, strata regarded as quaternary that have been tilted into an inclination of 65°. Furthermore, numerous faults furrow the country, while the parts that have been most disturbed, according to Macpherson, are upon the faults that terminate the crystalline mass of the Sierra Tejea and Almijara. The numerous thermal springs of the region are further evidences of the deep fractures that traverse it.

Similar conditions, dislocations, and recent age, are found in other regions subject to subterranean perturbations. They appear notably in that part of the Mediterranean basin which we have spoken of as especially agitated, although it is distant from volcanoes; in the Apennines, the Lebanon, and the mountainous masses of Dalmatia and Croatia bordering on the Adriatic. The configuration of the northern coasts of that sea, so exceptionally slashed and cut by deep indentations, results from the complexity of the fractures that have determined the outlines of their principal features. Even the chain of the Alps, where shocks are felt nearly every year, acquired its final relief only at a comparatively recent epoch. It is conceivable under such conditions that the interior masses are not yet at equilibrium nor wholly subsided, and that they contain vacant spaces affording room for further sinkings.

According to what seems to be the dominant opinion of the day, there are two kinds of earthquakes: those which are due to volcanic actions, and of which the vapor of water is the prime mover; and those which are the effect of such ruptures of the equilibrium of the solid

masses as we have just been considering. It is hard for the mind to admit two causes so different for phenomena which in most of their features so resemble one another. The demarkation between them is hard to define. On the western coast of South America and in Venezuela earthquakes facing volcanic ranges and those distant from such phenomena present the same manifestations. The supposition that the phenomena are due to the rubbing together of the solid parts of the crust also encounters a serious objection in the remarkable repetition of shocks during the same crises. In fact, this reiteration of shocks by the hundred and the thousand, for weeks and months, is one of the most characteristic accompaniments of earthquakes.

In view of these periods of disturbances, the cause, instead of being exhausted by a few shocks at short intervals, as would happen under the supposition that the first cause is the action of solid masses upon one another, should be one that could re-enforce itself after having been temporarily weakened. This is an essential fact, which any proposed solution must explain. We first remark that water, confined in a close space which it fills, will come, when it reaches a high enough temperature, to have a power which it is hard to represent in figures.

In nature, the tension of the vapor in the volcanic reservoirs is exhibiting its energy at every instant ; for that which forces the lava out of the crater of Etna, about ten thousand feet above the sea, can not be less than one thousand atmospheres. The conditions necessary to give such tensions can not fail to be realized in the crust of the earth at a certain depth, beyond the domains of real volcanoes, and principally under chains of mountains and dislocated tracts. It is an ascertained fact that, whatever may be the constitution of the ground, the temperature increases regularly as we descend to a lower depth. At the same time water tends to descend, under the joint influence of gravity and capillarity, and may continue to descend till it reaches the deep and hot regions where it can acquire a temperature that will render it capable of producing great mechanical and chemical effects. Hence we can hardly doubt that waters from the surface reach the internal regions, and then make us feel in the shape of tremors and rumbling the power and explosive force which they gain there.

The depth at which the agency from which earthquakes originate should be sought has been the subject of careful studies. The results indicate that it is not seated in the central parts of the globe. This is the inevitable conclusion from such cases as the earthquakes in Calabria, in which the disturbed area was very small.

It is probable that the consolidation of the deep parts under the dislocated regions and especially under chains of mountains of a relatively recent age is not yet completed, and that there are still interstices and interior cavities of high temperature which eventually became filled with water by the action of capillarity. Hence we find the

three conditions we have just been considering in the lower parts of the dislocated regions: cavities, water, and a high temperature, all constituting an agency capable of producing considerable dynamic effects at any moment. Suppose a barrel of powder exploded in a cavity situated a hundred metres underground. At the surface we would hear a rumbling explosion, and feel a vertical shock within a limited space, and an undulatory thrill over a wider circle. The phenomenon will be much like that of an earthquake, except that the essential element of repetition will be wanting; for all will be over with the first shock. But, in the majority of earthquakes, the shocks come in succession, as if the cause of them were a regenerating one.

Many ways may be conceived in which these enormous tensions may end in reiterated shocks, according to the hypothesis on which we place ourselves. Thus the water in a cavity having in time reached the temperature of explosion, suddenly displaces some of the walls of its prison. Hence, a first shock, followed by an expansion into the cracks and adjoining cavities, which have lower temperature and tension. Then, the pressure in the original focus of explosion having fallen off, the walls which had given way return upon themselves to their former position, to give way again when the primitive reservoir has regained its lost tension. This flow from cavity to cavity, which, instead of being continuous, is made by bursts and starts, may continue to be reproduced time after time till the principal reservoir is exhausted. But the mechanism is not destroyed then. During the period of calm, following the seismic period, it can be charged again. Something analogous to this takes place in volcanic eruptions, which are separated by the lapse of time necessary to recharge their apparatus by a slow alimentation. Furthermore, reservoirs of water may be suddenly displaced under the effect of contractions of the crust, and may thus be brought into contact with masses having a high temperature.

If we suppose a sea of melted matter to exist beneath the crust of the earth, we should have analogous effects whenever hydrated rocks, broken off from the shell, fall into the ignited masses.

The theory of the agency of vapor is also supported by the rumblings and subterranean thunders which sometimes continue for months and even for years without being attended by shocks, and for which it is difficult to imagine any other causes than sudden condensation, or a flow of gaseous matter at very high tension through a narrow orifice. The vapor, having escaped from its prison, must in many cases resume the liquid state very quickly, on account of the enormous expansion it undergoes. It also has to traverse miles of relatively cold rocks, more or less water-charged and full of cracks. It may thus contribute to the production of thermal springs. Examples are on record, too, of earthquakes, remote from any volcanic point, in which both hot water and gaseous matter have been seen to issue from crevasses.

Thus, the motive force of these formidable disturbances is always active under the feet of the inhabitants of many regions. Against the permanent danger that menaces them, men have at least the remedy of forgetfulness. — *Translated for the Popular Science Monthly from the Revue des Deux Mondes.*

THE TRADING-RAT.

By Mrs. E. D. W. HATCH.

THESE interesting rodents are dwellers in the Rocky Mountains and adjacent hills, and are known among us by various significant names, as mountain-rat, timber-rat, and trade-rat. The first, of course, refers to their native home; the second to the sound of their gnawing, scarcely to be distinguished from the sawing of timber; and the last to their peculiar system of barter or exchange, so curious a habit that it is doubtful if any other animal has ever been known to practice it while in a wild or untamed state.

These animals are much larger and stronger than the ordinary house-rat—so much so that cats are apparently afraid of them, and can not be induced to attack them. They are pretty, well formed, have very bright black eyes, prominent, beautifully shaped, pointed ears, and soft gray fur. Their tails are not rat-like, but are more like a squirrel's, only less bushy, being covered with fur.

Such keen, intelligent-looking little creatures are they that, but for our instinctive dislike to the name of *rat*, we should be strongly tempted to tame them as attractive and teachable pets. Until they learn that they have an enemy in man, they are quite unsuspicious, and will allow any one to walk up to them.

One of these rats being caught in the house, attracted by his size, I measured him: body, eight inches long; tail, eight inches; around his body, under his fore-legs, seven inches; ears, an inch and a half; fur beautifully fine, gray, with a darker shade, nearly black, running lengthwise down his back. He was very plump and fat, but I omitted getting his weight.

They haunt houses and camps near the hills, but seldom, if at all, those a few miles away. The peculiar trading characteristics natural to this little merchant, its habit of exchanging goods without a "by your leave," wise ways, and queer tricks, seem far more like reason than instinct. A few incidents which came under my own observation will illustrate this characteristic. Some men, passing through the country, camped in a deserted cabin, and, before wrapping themselves in their blankets for the night, they placed their bread for breakfast in a pan near the fire. On rising, to their dismay, not a crumb of

bread was left in the pan, but it was filled with old scraps of leather, chips, bones, moldy beans, rags, etc. Searching, they found, high up on a partly broken shelf, in an old tin can, their bread packed away with old bacon-rinds, bones, rags, and other trash.

In the house of one of my neighbors these mischiefs carried away a lot of Indian or corn meal, and in the meal-box deposited a quantity of bird-shot, which, mixed with the remaining meal, caused the housekeeper great dissatisfaction. In the same house a trunk was accidentally left open one night; in the morning a quantity of rice, bits of dried fruit, and some oats, were found mixed with loose coral beads and other small trinkets; it was an exercise of patience to separate the articles, as may be readily imagined.

With these traders exchange is no robbery, and distance small hindrance; they travel from their homes and go from barn to house, from loft to cellar, and through living-rooms (noiseless when acting as porters), with great speed and impartiality. A sheep-herder, returning to his camp from a town thirty miles away, brought home a fine new hat; placing the box on his table, he went away for the night. Returning, he found the box had been entered, the crown of the hat eaten entirely round, and the box then filled with wool, flannel rags, remains of food, wheat, and dried fruits. There was a sudden forced abandonment of that unsurveyed "squatter's claim."

Some ranchmen were gone haying for several days, camping away from home. After their return they soon learned that their quarters had not been unoccupied during their absence. A nest composed of wool and rags filled the flour-sieve left upon a shelf; next beside the sieve stood the coffee-box, in it had been left about a pound of good coffee; now the box was filled to the top, mixed with the coffee, moldy crusts, bones, and rinds, that had been scattered about the place. "When I threw it all out," said the man, who was telling me, "provoked as I was, I could not help noticing how *prettily* the nest was made up of gnawings of an old blue army-overcoat, red flannel shirt, and many white rags, put together so nicely and made so soft within." This morning, going to the store-house for a lamp-chimney, I found an ordinary glass chimney packed close with straw, grains of rice, oats, wheat, a few beans, and chips.

The mischief these rats can do in a single night is almost incredible. One, getting into a lady's room, stripped her house-plants of every leaf and blossom, and hid himself behind the wardrobe, where he was found next day, with a most singular accumulation of goods, among them many bits of paper, a quantity of raisins, a box of matches, some candle-ends, gnawed postage-stamps, and a lot of odds and ends. Nothing seems to come amiss, and they are particularly fascinated by anything that glitters; often carrying off knives, spoons, watches, and silver, and hiding them effectually.

They are "good providers," and in the fall build their nests, and

fill them with stores of eatables, the result of persevering foraging expeditions for their families before winter is on them. Under a large cottonwood-tree on a side-hill, partly underneath a fallen trunk, a party of us found a mountain-rat's nest. It was built up nearly two feet in height, the top or roof covering it sloped on all sides to shed rain or snow; tearing it to pieces, we found it was built closely of grass, moss, chips, bones, and many leaves of the cactus (which grows plentifully among the rocks); how they could cut off and convey this thorny stuff, working it up with the other material, in the close covering, is hard to understand. Away down, running in almost under the log so well built around, out of the reach of any possible moisture or cold, a clever little bed of wool was found, made for the young rats; this wool, of which there was a quantity, must have been collected bit by bit from the weeds through which the sheep passed, and from their corrals.

To reach this nest in the rat's house, there was quite a long, circuitous passage, entrance close to the ground, on the south side—a little den or hole to crawl through. In a little heap outside, not yet carried in among their provisions, but lying close by, we found more than a quart of fine, fresh-looking potatoes, brought from our own garden, and it is an unsolved mystery how the potatoes were taken there; with not a scratch or mar upon them, or the skin bruised or broken. The garden was a hundred feet away, considerably lower down, and a stream of water, an irrigating ditch, to be crossed to reach it. One person suggested that the rats might have rolled them all the way, and across some poles thrown over the stream.

Destroying this nest, a couple of rats darted up the standing tree, and there we were surprised to find another nest had been commenced in the forks of the tree. We destroyed this nest also; but here comes in another mystery, a puzzling question: How could the rats climb that tree and carry up stores for the winter? This nest was probably twenty-five or thirty feet from the ground.

I asked a ranchman a few days ago, who was talking about them, if he was afraid of them (I meant of their bite). "No," said he, "and they are not afraid of me; they have waked me many a time, sitting up on the floor of my cabin and rapping their tails like a dog!"

A description in Appletons' "Cyclopædia" seems in some respects to tally pretty well, under the name of "The Florida Rat." It describes these rats as "very abundant in the Southern Atlantic and Gulf States, and occasionally found in the West. The habits vary much in different localities, living in some places in the woods, in others under stones, or in the ruins of buildings; in swampy districts they heap up mounds, two or three feet high, of grasses, leaves, and sticks, cemented by mud; sometimes the nest is made in the fork or hollow of a tree; are very active, and excellent climbers; their food consists of corn, nuts, cacti, and crustaceous food, various roots, and fruits; disposition

mild and docile." Its most singular trait, its habit of barter, is apparently, if the same, unknown. He is not a thief like the monkey, who steals and makes no reparation, but, with a strange kind of honesty, whenever he helps himself he puts something (to his mind, perhaps, as valuable) in its place; he adapts himself to circumstances; there being neither corn nor shell-fish in the Northwest, he does very well without, and maintains a plump appearance upon something else. The habit of building here is in dry haunts, where it can find seclusion and secrecy.

Since beginning this article, I have met with an extract from Father Joseph Acosta's "Natural and Moral History of the East and West Indies," published at Barcelona, in Spain, in 1591, translated and printed in London in 1604, which seems a fair description of this little animal. Again, in "The Observations of Sir Richard Hawkins, Knight, in his Voyage into the South Sea, 1593," published in London, 1622, and still another published by a Spaniard, "History of Chili," published at Rome, 1646. In all these accounts there is a queer confusion of names. Sometimes these animals are spoken of as rats, again squirrels, then chinchillas; the covering of their skins is named indifferently, as it happens, wool or fur; color generally said to be gray.

From a natural history of Chili, published at Bologna, in Italian, 1782, translated 1810, I give the following extracts:

"The chinchilla is another species of field-rat, held in great esteem for the extreme fineness of its wool, if a rich fur, as delicate as the silken webs of the garden-spiders, may be so termed. It is of an ash-gray, and sufficiently long for spinning.

"The little animal which produces it is six inches long from the nose to the root of the tail, with small, pointed ears, a short muzzle, teeth like the house-rat, and a tail of moderate length, clothed with delicate fur.

"It lives in burrows underground, in the open country of the northern provinces of Chili, and is very fond of being in company with others of its species.

"It feeds upon roots of various bulbous plants, which grow abundantly in these parts.

"It is so docile and mild in temper that, if taken into the hands, it neither bites nor tries to escape, but seems to take pleasure in being caressed.

"If placed in the bosom it remains there, as still and quiet as if in its own nest. As it is in itself peculiarly cleanly, there can he no fear of its soiling the clothes of those who handle it, or of its communicating any bad smell to them, for it is entirely free from that ill odor which characterizes the other species of rats."

And he adds, which to us seems odd enough, about a little creature six or more inches in length, "For this reason it might well be kept in the houses, with no annoyance, and at a trifling expense, which would be abundantly repaid by the *profits on its wool*."

Another writer upon Chili, in 1824, speaks of the same animal and calls it a woolly field-mouse, which lives underground, and chiefly feeds on wild onions, saying that its fine fur is well known in Europe; that that which comes from Upper Peru is rougher and larger than that from Chili, but not always so beautiful in color. Still another writer, speaking of the same, calls it chinchilla; says that it usually sits upon its haunches, and is even able to raise itself up and stand upon its hinder feet; that it feeds in a sitting posture, grasping its food and carrying it to its mouth by means of its fore-paws, and adds, "The ancient Peruvians were a very industrious people, and they made of this fur wool coverlets for beds and valuable stuffs." A lady, who was presented with a living specimen from Peru, kept it for many months, feeding it upon hay, clover, and succulent roots. She then presented it to a zoölogical society, with the information that her pet was good-tempered, mild in its disposition, and, when allowed to run about the room, very tame and playful, delighting in feats of agility, often leaping to the height of the table.

These descriptions, written many years ago, with others at hand not necessary to repeat, apply well to the trade-rat of the Rocky Mountains, save that they do not mention the creature's curious habit of barter.

I have already spoken of their great strength and celerity of movements. To an observer these traits are a never-failing surprise. If a light is steadily burning and all is quiet, they are easily watched, darting back and forth, carrying goods each way—round trip, so to speak, and often long trips. I have known them to bring nails, bits of iron, screws, and other things left about the sheds, quite a distance to the house, place them on shelves, boxes, or kegs, just as they fancied, but all in some selected spot, carrying back from cellar and storehouse dried prunes, apples, rice, and all kinds of eatables. If, working in the dark, the drawing of a match, a slight noise, or sudden light will cause them to vanish like a flash.

They seem, too, to have a fancy for certain colors, particularly bright red, and will soon make away with garments of this color, and attach them to their nests. There may be something attractive in the dye, but, knowing their partiality for glittering, shining objects, I am inclined to think they have also an eye for color.

With all their curious and often annoying tricks, they are wonderfully ingenious and persevering, and certainly possess the attributes of a good business man in their energy, industry, foresight, and a desire to make provision against a time of need.

TISSUE-SELECTION IN THE GENESIS OF DISEASE.

By W. HENRY KESTEVEN, M. R. C. S.

IT has occurred to the writer that the adoption of the germ theory of disease necessarily involves the application of the theory of evolution, and that here may be found a means of accounting for the genesis of the various forms of disease. Germs are living matter; they must therefore be under the influence of those laws and forces which condition all living matter. The most important of these, or the one that most interests us in the present connection, is the law of natural selection; and it must be that germs, in common with other forms of life, are under the influence of this law in some shape. Natural selection is a general term which embraces all other modes of selection, or provision for the "survival of the fittest." Among these is sexual selection, and, taking a broad view, we may also include selection by man. In order, then, to the attainment of greater exactness, may we not give a name to that form of natural selection which has been potent in bringing about the variations in the characteristics of those germs to which the differences in the forms of disease are due? Such a term may be found, I would suggest, in "tissue-selection," as indicating the special means whereby the constitution of the germs has been modified. The actual origin of the bodies which have received the names of germs is not at present determinable, and to say that they do not originate *de novo*, in decaying matter or elsewhere, is only to reaffirm the axiom now pretty generally admitted, *Omne vivum e vivo*. The fact that meets us here is that these germs, call them bacilli, vibriones, bacteria, or what we will, are met with almost universally in the atmosphere that we breathe. It is with the "why and the wherefore" of their existence that we are concerned. In looking for this, it will be necessary to consider the facts of the life-history of these germs, and to try to discover how they have been and are influenced by their surrounding conditions. We find that the conditions favorable to the full vital activity of these germs are a moderate temperature, moisture, and a resting-place or nidus in some organic matter whose chemical constitution enables it to afford the pabulum necessary for the maintenance of their existence. On the other hand, the influences antagonistic to their well-being are excessive heat or cold, the action of certain chemical bodies, and a condition of dryness. The last is certainly prejudicial, as it seems to hinder their full vital activity. At the same time it can not be considered absolutely obnoxious, as it is the means which favors their locomotion in the atmosphere. Putting aside, for the mean while, the thermometric and atmospheric conditions, we shall see that the

condition which most concerns us is that of a favorable nidus. A favorable nidus is one in which the germ is enabled to carry on its full vital functions, and to propagate its kind. It is therefore manifest that the constitution of the nidus must be free from elements antagonistic to such vital functions. It must not be too hot, or too cold, or too dry, and its chemical constitution must be favorable. Experiment has proved that oxygen in excess is deleterious to these organisms; its absence, entire or partial, will then be one of the requisites in this chemical constitution of the nidus. Is not such nidus best found in decaying or degenerating animal tissue? Where there is full vital activity in any animal tissue, the blood which nourishes it keeps it duly supplied with oxygen. In healthy tissue, then, we have a condition unfavorable; but when from some cause the nutrition of the tissue is interfered with and a condition of degeneration is induced, this antagonistic element is removed or at least diminished, and the tissue affords the nidus favorable to the vital phenomena of the germs. These vital phenomena are perhaps best studied in the analogous case of the spores of yeast (*torula cerevisiæ*). When this, which is to all intents and purposes a germ, is placed in favorable circumstances, its activity commences, it rapidly multiplies and gives rise to changes in the surrounding material. In this case we call the process "fermentation." A germ, bacillus, bacterion, or vibrio, when placed in relation to tissue which affords a favorable nidus, assumes its full vital activity; it multiplies and gives rise to changes in the tissue with which it is in contact. These changes we call "inflammation." In fact, it would appear that these germs in one sense fulfill the part of Nature's scavengers, and by setting up inflammatory changes in degenerate tissues lead to their removal. Be this as it may, the diseases to which the germs give rise are all more or less of an inflammatory nature.

Thus, then, it would seem that one of the chief vital functions of these germs is to excite an inflammatory process in degenerate tissue. Is it not conceivable that germs may have existed, or even do still exist now, whose function is strictly limited to action on degenerate tissue?—that this may perhaps have been the limit strictly assigned to them? Let us suppose this to be the case, and see how, from this limited condition, germs have acquired power to overstep these limits, and thus to give rise to the protean aspects of disease that we now meet with. What has caused variation in the animal world but the influences of surrounding circumstances? In the relationship of the germs and the degenerate tissue, it is plain that in one sense the germs are the active, and the tissue the passive, elements. But, looked at from the tissue point of view, it will also appear that this passive condition possesses considerable indirect influence on the germs; that, indeed, "passive" is hardly the word to express the action which must largely modify their constitution. It would be impossible for the germs to live, to grow, to multiply on a certain tissue without be-

coming imbued with certain characteristics of that tissue. Hence a difference, a variation, between the parent germs and their offspring.

Now, the one characteristic of the tissue which most strikes our attention is its degeneracy, and this degeneracy must exert its influence on the organisms which depend upon it for existence, so that in the thus derived organisms we have the germ vitality and function, *plus* a certain amount of degenerate tissue characteristic. Germs thus modified and brought into contact with tissue of the same kind, though less degenerate, will, in virtue of this constitutional modification, stand a better chance of establishment thereon, at the same time adding to the degenerate condition with which they meet in the new tissue the characteristics of the degeneracy of tissue they have left. The effects thus produced will be more acute, the constitution of the germs further modified, and their power increased. Hence it is possible to conceive that if by any chance a condition of tissue which could be called perfectly healthy was to be anywhere met with, even this tissue might in time become subject to the influence of these organisms. Of course tissues may be more or less susceptible to their influence, more or less healthy, but it is more than doubtful whether it can be positively said of any one tissue that it is absolutely healthy, any more than it can be said of the individual man or woman. It is therefore possible to conceive that at some time or other there has existed only one kind of germ, that variations from this one type have arisen in consequence of the modification wrought upon different individuals by their chance falling upon this or that degenerate tissue. Variation must lead to specialization, and finally we find diseases all dependent upon the action of germs, as different from one another as one species of animal differs from another.

But there is another direction in which these germs must have been modified fully to account for the differences we now see. Germs may still exist which have only the power of exciting a simple inflammation in any degenerate tissue. Others, a step more advanced, are found, whose action is more potent, which have attractions for the one special tissue in which they have been bred; while others are capable of exciting the special form of inflammation in which they have had their origin, in tissues various in structure and composition. This power or, rather, increase of power—in other words, further variation in constitution—thus displayed is only to be accounted for by the supposition that its acquisition is secondary to the act of establishment, and that it is brought about by means of the blood itself receiving some of the germs and conveying them to some other tissue, on which, in virtue of its degeneracy, and possibly of a further modification, they have themselves received from the blood, they are enabled to effect a settlement. It must also be remembered that their modification, which enables them to select a tissue for their primary and more virulent action,

does not deprive them of their original power of attacking degenerate tissue. It is simply an additional power, rendering them more potent when brought into contact with tissue possessing certain characteristics. These characteristics of the tissue originally attacked may determine the character of the action of the germs on other tissues, and thus enable us to recognize a relationship in the morbid influences at work in different tissue—as, for example, in syphilitic disease. If it is a fact that the tissue originally attacked modifies the constitution of the germs, it is surely more reasonable to suppose that the special characteristics thus impressed upon the germs are those which give the family likeness to the descendants of these germs, rather than to suppose that this morbid family likeness exists in the germs before ever they have been brought into contact with any form of degenerate tissue. In other words, may not a bacterion, pure and simple, by being brought into contact with some form of degenerate tissue, acquire or give rise to other bacteria which possess certain characteristics which we recognize as being those of special disease, and that those characteristics enable them to excite a similar form of disease in the new nidus? It is also conceivable that as different diseases are more or less wide-spread or of older standing, so the germs given off from tissues affected by these diseases will have more and more power of affecting tissues less and less degenerate, even to the point of a possible condition of actual health. So, for example, the germs of scarlet fever or measles have actually acquired great power over the tissue which they primarily affect; whereas in the case of tuberculosis it is more than doubtful whether the actual presence of a tubercular condition of degeneration in the tissue, to a definite extent, is not necessary before the germs can find a suitable nidus in that tissue. Of course, germs derived from a tubercular origin will have more influence over tissue which is not so much affected than germs which have not such tubercular origin. It is, in fact, simply a matter of degree of degeneracy. May it not be this which enables persons free from tubercular taint to brave the assaults of germs be they ever so virulent?

The above are only one or two examples showing the different powers possessed by germs derived from the different forms of disease. The list of examples might be almost indefinitely prolonged. But the result would only be to show that different diseases have different powers of affecting the animal body, a fact already well known. It is the design of this paper to show that possibly these powers have been acquired by the action of some form of natural selection, here propositionally called "*tissue-selection*," on the germs which inhabit the air we breathe and the water we drink, such action in the course of long ages having given rise to germs possessing special powers, and being now apparently unrelated to each other in any way. The intermediate steps between a simple germ and such a highly modified one, as, for

instance, the variolous or tubercular germ, may be difficult to trace, for as we at present see these germs it is as though we were looking at a picture or photograph of a family tree in which the greater part of the trunk and larger branches have become obliterated, having only the terminal twigs visible, with no apparent connection between them. —*Lancet.*

SKETCH OF PROFESSOR H. A. NEWTON.

THE President of the American Association for this year, Professor HUBERT ANSON NEWTON, of Yale College, is distinguished not less for his researches in the higher mathematics, which mark a distinct advance in the American study of that science, than by his contributions to the determination of the orbit of the November meteors, in which he was a pioneer.

Professor Newton was born at Sherburne, New York, on the 19th of March, 1830. Having made his preparatory and academical studies in the schools of his native town, he entered Yale College in the second term of his Freshman year, and was graduated from that institution in 1850. He then spent two years and a half in studying mathematics at home and in New Haven, and was appointed tutor in the college in July, 1852. Entering this office in June, 1853, he had the care of the whole department of mathematics from the first; for Professor Stanley was ill, and died in the spring of 1853. He was elected Professor of Mathematics in 1855, and was given permission to spend a year in Europe. Returning, he assumed the chair in 1856, and has ever since been engaged in the active discharge of the duties of the professorship.

His earlier works appear to have been principally directed to those methods in higher geometry, the power and elegance of which, says his biographer in the "History of Yale College," have been so highly shown in the works of Chasles and others. Among the most conspicuous of them is a memoir "On the Construction of Certain Curves by Points," published in 1861 in the "Mathematical Monthly," which is characterized as one of those contributions to abstract science which have been, unfortunately, too rare in this country. A later, no less remarkable paper was one of joint authorship in the Transactions of the Connecticut Academy of Sciences on "Certain Transcendental Curves."

His most important service to science, and the one by which he is probably most widely known to the world of students, is the work which he performed in the study of the November meteors. These phenomena, which had been occasionally mentioned at previous periods of their recurrence without apparently any adequate comprehension of

their significance, were first carefully observed by Professor Denison Olmsted in 1833, who gave much attention to the question of their nature and origin. But, as Professor C. S. Lyman states in his biography of Professor Olmsted, it was not till thirty years after his and Professor Twining's studies of the subject "that the labors of Professor Newton in this country, and of Professor Adams and others abroad, made it possible to designate the precise orbit of the November stream, and to identify it with that of a comet having a period of thirty-three and one fourth years." The phenomena continued to have diligent observers at New Haven, prominent among whom was Mr. Herrick, the librarian, and afterward, till 1862, the treasurer of the college. At the time of his death, the biographer in the "History of Yale College" records, "Professor Newton was already engaged in organizing combined and methodical observations on shooting-stars, and in collecting and publishing in the 'Journal of Science' the results of independent observers. Under his supervision a map of the heavens was prepared, which was published by the Connecticut Academy, and could be used by observers to mark down the apparent paths of the meteors. A rich harvest of observations was thus obtained by zealous laborers in various parts of the country, many of whom had been interested and trained in the work by Professor Newton. The separation of the precious grains of truth from the chaff—the perception of the constant amid the accidental, of fixed laws disguised by the errors of observations made under circumstances which precluded the use of instruments of precision—is, however, the more difficult part of such investigations. The published results of Professor Newton's studies in this direction are mostly to be found in the 'Journal of Science' and in the 'Memoirs' of the National Academy. The memoir read to this Academy a few years ago is an almost exhaustive discussion of the phenomena exhibited by the sporadic shooting-stars. He has also contributed admirable summaries of what is known in respect to the laws of meteors to the new edition of the "Encyclopædia Britannica" and to "Johnston's Cyclopædia."

"But the investigation which has been followed by the most remarkable results relates to the November meteoroids, and was based upon researches into early records of remarkable star-showers. From such records, Professor Newton showed that the period of revolution of these bodies must have one of five accurately determined values. From the same sources he determined the secular motion of the node of their mean orbit. The five values of the period, with the position of the radiant point, which had also been determined, would give five possible orbits. The real orbit could be distinguished from the others, as Professor Newton remarked, by the calculation of the secular motion of the node due to the disturbing influence of the planets for each of the five orbits. This calculation was subsequently undertaken by Professor Adams, of Cambridge, England, and the real orbit was ap-

parent from the coincidences of the early observations (the observed and calculated values were 29′ and 28′ respectively). These calculations of Professor Adams, which fix beyond a doubt the position of the mean orbit of the November meteoroids, were made shortly after their appearance in 1866. The publication, about the same time, of the orbit of the first comet of 1866 revealed the fact that that comet and the meteors travel in nearly coincident orbits, and have an intimate relation one with the other. To appreciate the rapid advance of this department of astronomy, we must contrast this certain knowledge with the conflicting views which prevailed at the time of their first appearance, in 1833, with respect to the nature of the phenomenon of which they were the cause. In recognition, presumably on his part in these achievements of science, Professor Newton was elected, in 1872, associate of the Royal Astronomical Society."

Professor Newton has been for more than a dozen years one of the associate editors of the "American Journal of Science," and most of his scientific articles have been written for its pages. He was one of the fifty members appointed by the act of Congress constituting the American Academy of Sciences. In 1860 he was elected a corresponding member of the British Association for the Advancement of Science. He served in 1875 as Vice-President of Section A of the American Association for the Advancement of Science, at its Detroit meeting.

His address on this occasion took the form of a strong plea for more study of mathematics by American men of science; not for the sake of its place in education, but for the advancement of the science itself, and for the assistance that might be derived from it in the pursuit and enlargement of other branches of knowledge. Whatever might be the reasons for it, he said, "the unpleasant fact is that the American contributions to the science of quantity have not been large. Three or four volumes, a dozen memoirs, and here and there a fruitful idea having been selected from them, there is left very little that the world will care much to remember. I refer, of course, to additions to our knowledge, not to the orderly arrangement of it. To make first-rate text-books, or manuals, or treatises, is a work of no mean order, and I would not underestimate it. In good mathematical text-books we need not fear comparison with any nation. But so few additions have been made to our knowledge of quantity that I fear that the idea has been quite general among us that the mathematics is a finished science, or at least a stationary one, and that it has few fertile fields inviting labor and few untrodden regions to be explored. Hence many bright minds, capable of good work, have acted as though the arithmetic, the algebra, and the mechanics which they studied covered all that is known of the science. Instead of going on in some path out to the bounds of knowledge, as they had perhaps the ability to do, they dug in the beaten highways, and with care

planted seed there, hoping for fruit. How much such ill-directed thought has been spent on the theory of numbers, on higher equations, on the theory of the tides, etc., which, if rightly expended on some untrodden though humble field of the science, might have really added to human knowledge! And yet hardly any science can show, on the whole, a more steady progress, year by year, for the last fifty years, or a larger and healthier growth, than the science of quantity. Here, too, as in every other science, the larger the field that has been acquired, the larger its boundary-line from which laborers may work out into the region beyond. An individual may wisely neglect one science, in order to work in another. But a nation may not. For the healthy growth of all, each science should be fostered in due proportion. But the mathematics has such relations with other branches that neglect of it must work in time wider injury, I believe, than neglect of any other branch."

The view expressed in the last sentence of this extract was sustained by the citations of instances and ways in which the questions of quantity and proportion have to be dealt with at some stage in almost every branch of scientific investigation.

Of the value of mathematics as an instrument of research in other departments of knowledge, he says: "Again—I argue from a natural law of succession of the steps of discovery in the exact sciences—we first see differences in things apparently alike, or likeness in things apparently diverse, or we find a new mode of action, or some new relation, supposed to be that of cause and effect, or we discover some other new fact or quality. We frame hypotheses, measure the quantities involved, and discuss by mathematics the relations of those quantities. The proof or the disproof of the hypotheses most frequently depends upon the agreement or discordance of the quantities. To discover the new facts and qualities has sometimes been thought to be higher work than to discuss quantities, and perhaps it is. But at least quantitative analysis follows qualitative. It is after we have learned *what kind*, that we begin to ask *how much?*"

Professor Newton is a member of several other learned societies in this country; he is a member of the Publication Committee of the Connecticut Academy of Sciences; is a trustee of the Winchester Observatory; and is the author, in Professor Kingsley's "History of Yale College," of the sketch of Professor Alexander Metcalf Fisher, one of his predecessors in the chair of Mathematics, who died by shipwreck at an early age; and of the account of Winchester Observatory.

EDITOR'S TABLE.

OFFICIAL SCIENCE AT WASHINGTON.

MUCH has been said in the newspapers during the last few weeks about the mismanagement and irregularities that have been disclosed by official inquiries into the administration of the United States Coast Survey. The superintendent of that branch of the public service has been retired from his office; the assistant in charge was also removed, and then restored; and charges have been made against other parties. It is alleged that expenditures are out of all proportion to results, that the service is inefficient, and the department much demoralized.

The first question, of course, in regard to such grave accusations is, to what extent are they true? Is the case as bad as alleged, or only an exaggeration of such defects as are always incident to the administration of governmental affairs? It seems that a committee of investigation was appointed by the Treasury Department to look into the working of the Coast Survey. A committee charged with so serious a duty should certainly have made the most careful and searching inquiry, should have given the accused officers the fullest opportunity of defending themselves, and should have published their results in an explicit and authentic form. We are not aware that this has been done; and if so, common justice requires that judgment should be suspended until decisive evidence is forthcoming, because innocence is to be presumed until guilt is *established*. Upon these points the following remarks from an excellent editorial in "Science" are so appropriate and fair as to be worthy of quotation:

Without the slightest disposition to screen official mismanagement, if it has been discovered, we must caution our readers against giving credence to insinuations and rumors. All who are under implied censure have a right to be fully heard, and to bring all the facts which are explanatory of their conduct to the eye of a qualified tribunal. They have a right to protest against the arbitrary exercise of personal authority, or against the judicial methods of a star-chamber or a drumhead court-martial. No political purpose, no personal dislike, no disbelief in science, should be allowed, unquestioned, to throw discredit upon a branch of the public service, or dishonor upon a corps hitherto regarded as exemplary in all its official work.

The work of the Coast Survey, during its long history, has been of the highest character. For nearly seventy years it has been approved by successive Congresses and administrations, and by navigators, merchants, and men of exact science. It has received the highest encomiums of foreigners who were qualified to judge of its merits, and were interested in pointing out its defects. The five superintendents—Hassler, Bache, Benjamin Peirce, Patterson, and Hilgard—have each, in different ways, improved its methods and upheld its efficiency. The officers just displaced have grown up in the service, and have won promotion by the ability and fidelity with which they have discharged their great responsibilities. The presumptions of official rectitude are in their favor until positive faults are pointed out. They are entitled by the principles of good government, as well as by their individual services, to all the opportunities they may desire for explanation or defense; and any premature opinion is unfair, especially if it is affected by personal prejudices, or is based upon a lack of appreciation for scientific researches.

In the conduct of such a bureau as the Coast Survey, a large amount of discretion must be left to the chief. He, and he only, can determine a vast number of questions which pertain to the selection of assistants for different kinds of work, the choice of fields of labor, the discrimination between services which have an obvious relation to some immediate want of the public, and those which may be just as serviceable, but are recondite, and unintelligible to the uninformed. It is impossible to mark out the duties of the highest assistants by such rules as may be applied to the clerical services of an ordinary

counting-room. In order that the results of the survey may be accurate and trustworthy —the only results which are worth having— costly instruments must be bought and used, and must afterward be thrown aside, because other instruments are better, or because their work is done. Still larger outlays are requisite, in order that elaborate and important fundamental inquiries may be prosecuted by men who are trained to exact scientific methods. A staff of learned and experienced investigators is absolutely essential to the conduct of such a national undertaking as the Coast Survey.

Nevertheless, all this scientific research is appreciated by a very small number of persons. Indeed, the more valuable it is, the less obvious may be its merits. Every seaman knows the value of a good chart: not every seaman, not every scholar, not every statesman, knows the conditions by which a good chart is produced. It is only the expert who appreciates the subtile sources of error which must be eliminated: he only knows the infinitude of mathematical, physical, astronomical, and geodetic problems, which are involved in an endeavor to portray faithfully such a coast-line as that of the United States, and to keep the portrayal in accurate correspondence with the changing sands.

There is undoubted weight in the consideration here urged that much of the work of the Coast Survey is of a kind that can be but imperfectly judged by the public, and must be left to the men of science, who can best appreciate its desirableness and its difficulties. This is also the ground taken by the American Association for the Advancement of Science in reviewing the subject. At their recent meeting in Ann Arbor, Professor S. P. Langley proposed the following series of resolutions, which, after discussion, were passed unanimously:

Whereas, The attention of this Association has been called to articles in the public press purporting to give, and presumably by authority, an official report of a commission appointed by the Treasury Department to investigate the condition of the United States Coast-Survey Office, in which report the value of certain scientific work is designated as meager; and

Whereas, This Association desires to express a hope that the decision as to the utility of such scientific work may be referred to scientific men:

Resolved, That the American Association for the Advancement of Science is in earnest sympathy with the Government in its every intent to secure the greatest possible efficiency of the public service.

Resolved, That the value of the scientific work performed in the various departments of the Government can be best judged by scientific men.

Resolved, That this Association desires to express its earnest approval of the extent and high character of the work performed by the United States Coast Survey, especially as illustrated by the gravity determinations now in progress, and to express the hope that such valuable work may not be interrupted.

Resolved, That this Association expresses also the hope that the Government will not allow any technical rule to be established that shall necessarily confine its scientific work to its own employés.

Resolved, That in the opinion of the American Association for the Advancement of Science the head of the Coast Survey should have the highest possible standing among scientific men, and should command their entire confidence.

Resolved, That copies of these resolutions shall be prepared by the General Secretary and certified to by the President of the Association and by the Permanent Secretary, and shall be forwarded to the President of the United States, the Secretary of the Treasury, and given to the press.

The subject was called up and acted upon because of the recent arraignment of the Coast Survey, as stated in the first preamble. In the second the hope is expressed that the decision in regard to the utility of such work—that is, Coast Survey work—may be left to scientific men. But it will be observed that the second resolution covers wider ground, affirming that all "the scientific work performed in the various departments of the Government can be best judged by scientific men."

Now, certainly, nothing can be more true than that scientists are the best judges of scientific work; and, as between these and the officials that are over them, the case may be stated still more emphatically. The successful pol-

iticians who get possession of high government offices are apt to be especially incompetent in all matters of science; and, consequently, they must, as a class, be the worst judges of the technical labors of scientific men. What, then, is to be done? The politicians impeach a scientific department for inefficiency, and the scientific men reply by a virtual protest against their capacity to judge of the conduct they condemn. In this they are right; but is it therefore inferable that the scientists are to be left to themselves, and exempted from scrutiny and criticism in the management of their affairs? This assuredly will not do; for if scientific men are qualified on one side, they are disqualified on another and very important side. Like other men, they are self-seeking, ambitious, and have their personal ends to gain. Can we assume that morally they are any better than their neighbors; or that, if they get possession of place and power, they will not use and pervert them to the promotion of their selfish objects? It is to be hoped that in the future science will become so developed as to react upon character and give us men morally as well as intellectually superior; but we are far from any such happy result as yet. Government has boundless wealth at command; it is a mighty patron. Everybody is tempted to get some private advantage through its influence, and scientific men are no exception to their fellow-citizens in exemplifying the general passion, and in desiring to get a share of government patronage. The "scientific politician" has made his appearance in Washington, and the political element in him will dominate the scientific. That he will be a lobbyist and intriguer, and become skilled in the art of getting favors and appropriations from Congress, is but to say that he will work according to his opportunities, objects, and the nature of the materials to be manipulated. An unsupervised and irresponsible scientific department at Washington would be run in the interest of its sharpest managers, would be filled with sinecures, give the least results at the greatest expense, while these results would be aggravated by the sense of exemption from criticism.

We draw a different conclusion from the fact that scientific men are the best judges of their own work, and the politicians who have got the national offices the poorest judges of it. We infer that duties which those officers can not perform in a proper manner they should not undertake. The policy of extending what may be called Government science at Washington is a bad one; whatever is indispensable must be tolerated, but with this qualification the less we have of it the better. The Coast Survey is a work of undoubted national necessity. Its investigations are essential to the national defense; it was begun long ago, in a small way, with no reference to any Government policy respecting the promotion of science; and it has been systematically prosecuted as a matter of unquestionable public importance. But the modern extensions of Government science, as the Department of Agriculture, for example, stand upon no such ground. They have not been called into existence by any special or urgent needs of the state, or to subserve any legitimate function of Government; but they have come through the agency of scheming and ambitious scientific men who sought official power for the advancement of their own objects. Under such inspiration the national Government has entered into rivalry with the private investigators of the country to promote research, develop resources, and accumulate useful knowledge for the people. Millions of money are now spent on investigations of all kinds, on collections and surveys, buildings, apparatus, salaries, and publications made at extravagant cost, and which are without that warrant of necessity which should be

the sole reason of any scientific undertaking by the state.

How the immense system of official science at Washington, which Government neither called for nor is competent to supervise, has gradually grown up under outside management, is easily explained. Alliance with politics has been very sedulously and skillfully cultivated by our leading scientific men. The most decisive step in this direction was taken a few years ago, in the organization of the National Academy of Sciences, an institution copied after an old French model. Through its act of incorporation a limited and select number of men became scientific leaders by national authorization. It was a specious and insinuating project, offering itself as a kind of bureau of advice to Congress on all scientific matters. Money was not solicited: the *savants* were to serve the state for nothing. It was to be a Washington institution, pledged to hold meetings at the capital permanently. The headquarters of the Coast Survey were already established there. The United States Government had accepted the magnificent bequest of Smithson, and established a national institution "for the increase and diffusion of knowledge among men"; and the newly instituted Academy of Sciences became the agency for combining the elements to secure the extension of Government patronage to all kinds of scientific undertakings. The tendency to centralization and the enlargement of Government powers, after the war, greatly favored the accomplishment of the work. The great extensions of state education also favored it. A splendid national university, with a twenty-million endowment by the General Government, was strenuously advocated. Everything was thus propitious to the multiplication and consolidation of scientific departments, and to the general plan of employing scientific men to carry on their inquiries at the expense of the state, and under the direction of Government.

For many and urgent reasons we hold that our overgrown Government science ought to be arrested and retrenched. That administrative officers are bad judges of it is one of them. But, even if this were not so, the policy would still be thoroughly objectionable. The promotion of science is not an object for which Government exists. The civil authority has its legitimate duties, and can only perform them by being confined to them. It is the business of Government to maintain the order of society and the rights and liberties of individual citizens by the establishment and enforcement of wise laws; and the sole condition on which this can be accomplished is that the lawmakers and law-executors shall allow nothing to interfere with this supreme duty. By attempting to do everything else this is neglected, and the multiplication of government functions ends in the defeat of the objects for which Government exists. We do not say that Government denies the rights of foreign authors and leaves them a prey to American plunderers because it has gone into the promotion of science; but we do say that its absorption in business interests and enterprises has deadened its moral sense so that it has little care about a gross delinquency which is a scandal to the American name throughout the world. Justice between man and man, the first condition of all sound prosperity in communities, can only be enforced by the civil authority; but science can be advanced by private enterprise, individual interest and effort, and voluntary association, better than by state regulation, and there it is better that the Government should leave it.

LITERARY NOTICES.

COLLECTED ESSAYS ON POLITICAL AND SOCIAL SCIENCE. By WILLIAM GRAHAM SUMNER, Professor of Political and Social Science in Yale College. New York: Henry Holt & Co. Pp. 173. Price, $1.50.

THIS volume consists of discussions upon the following subjects: "Bimetallism";

"Wages"; "The Argument against Protective Taxes"; "Sociology"; "Theory and Practice of Elections," Parts I and II; "Presidential Elections and Civil-Service Reform"; and "Our Colleges before the Country." These are all "topics of the time," dealing with questions not only of great public moment, but which are being much agitated in many quarters. The volume is therefore timely in its appearance, and, more than this, it is the kind of book that is greatly needed. In reading it, we have been much reimpressed with the author's rare ability in handling economical and social questions. A clear, logical, independent thinker; a sound theorist, because he always defers to facts; a practical man, because he trusts in established principles; and withal a vigorous, pointed, and attractive writer, Professor Sumner is the man to do eminently valuable work in educating the public mind on subjects of economical and social science. And sound teachers upon these subjects are none too numerous. The propagators of error, in numberless forms, have the field. Some are misled by half-knowledge, some prejudiced by party feeling, some perverted and blinded by self-interest, some fascinated by specious hobbies, so that the press teems with magazine articles, pamphlets, and books, not calculated, to say the least, to strengthen scientific conceptions, or to bring men into the agreement of reason on the various topics of public and social concern. Perhaps the worst of it is that the effect of all this chaos of opinion is to undermine confidence in principles and all belief in the possibility of anything like valid and trustworthy social and political science. In the present state of things, where great pecuniary interests are involved, the temptation to favor this view is strong. No service, therefore, is more important to the community than to strip away the multitudinous fallacies in which these subjects are involved, and to show that there are clear, comprehensive, and solid principles governing social and political phenomena which must be recognized and trusted before society can realize anything like permanent prosperity. This is the kind of work which Professor Sumner is eminently fitted to accomplish, and we cordially welcome his present work, as we have welcomed all his previous books, because it brings out and popularizes views which it is of the utmost moment that our citizens should understand and maintain. We can here give no indication of the doctrines expounded in the varied discussions of the work, and must be content to urge, especially upon our young men, that this is the kind of book to be thoroughly studied, until its contents are assimilated and reduced to an established political and social creed.

THE MICROSCOPE IN BOTANY: A GUIDE TO THE MICROSCOPICAL INVESTIGATION OF VEGETABLE SUBSTANCES. From the German of Dr. JULIUS WILHELM BEHRENS. Translated and edited by Rev. A. B. HENRY, assisted by R. H. WARD, M. D. Boston: S. E. Cassino & Co. Pp. 466, with Thirteen Plates. Price, $5.

ACCORDING to the translator, this treatise occupies a field almost entirely to itself in the botanical literature both of Germany and now of the English-speaking world, and it is published with the hope that its influence will be to stimulate in this country investigations into the deeper problems of plant-life. The study of the literature of the subject shows that there is an open field for American botanists, for existing works almost exclusively involve the results of German research, while a few are of French origin, fewer still of English, and none whatever of American. The first purpose of the work is to guide students in all those inquiries relating to the physical products of cell-life in plants which may be conducted under the microscope, by means of chemical and other reactions. While it deals with the anatomical constitution of the cell, and of plant-tissue, its inquiries relate much more to physiological and biological processes than to matters purely anatomical and histological. The part of Dr. R. H. Ward in the preparation of the work consists in the revision of the two chapters which deal with the microscope and its accessories; and in these considerable changes have been made, as is proper in a work of the kind intended for American study, in the omission of illustrations and descriptions in the Continental style, which is comparatively unused and unavailable here, and the substitution of American forms. All

the matter introduced by the American editors is distinguished by plain typographical devices.

THE TREATMENT OF OPIUM-ADDICTION. By J. B. MATTISON, M. D. New York: G. P. Putnam's Sons. Pp. 49. Price, 50 cents.

THIS work embodies the substance of a paper read at the last meeting of the American Association for the Cure of Inebriates, and details the author's special method of treatment, which he has successfully practiced for several years. The author maintains that opium-addiction is a disease, seldom a vice, and should be treated as a disease. He advises against breaking off the practice abruptly, while he finds the other ordinary method of treatment, by gradual decrease of the opiate with tonics, inconveniently slow. His own method is a mean between the two extremes, and is based on the power of certain remedial resources to control abnormal reflex sensibility; and he claims for it the advantages of minimum duration of treatment and maximum freedom from pain.

THE FIELD OF DISEASE: A BOOK OF PREVENTIVE MEDICINE. By BENJAMIN WARD RICHARDSON, M. D. Philadelphia: Henry C. Lea's Son & Co. Pp. 737.

THE author has written this work, he says, "for those members of the intelligent reading public who, without desiring to trench on the province of the physician and surgeon, or to dabble in the science and art of medical treatment of disease, wish to know the leading facts about the diseases of the human family, their causes and prevention. Any one, therefore, who opens this book with the expectation of finding in it receipts and nostrums will not have that expectation fulfilled, and will discover reference to no remedies except such as are purely preventive in character." The old historical terms are used in preference to the new; that classification of diseases is preferred which has descended from the best scholars in medical science and art, and which is best known to the people at large. Of the relative value of curative and preventive medicine, the latter "is not a science, it is not an art separated necessarily or properly from so-called curative medicine. On the contrary, the study of cure and prevention proceed well together, and he is the most perfect sanitarian, and he is the most accomplished and useful physician, who knows most both of the prevention of disease and of the nature and treatment of disease; he who knows, in fact, the before and the after of each striking phenomenon of disease that is presented for his observation." The investigation of the subject is directed to the tracing of diseases from their actual representation, as they exist before us, in their natural progress after their birth, back to their origin, and, as far as is practicable, to seek the conditions out of which they spring; and, further, to investigate the conditions, to see how far they are removable and how far they are avoidable.

THE WINDMILL AS A PRIME MOVER. By ALFRED R. WOLFF, M. E. New York: John Wiley & Sons. Pp. 159. Price, $3.

THERE may have been a time when windmills were considered antiquated and of no further use, but it is so no longer. These simple and economical sources of power are quite generally employed in all parts of our country, and their use is increasing, and, according to Mr. Wolff, it is now greater than at any other period in the history of the world. "To place the number of windmills at work in America," he says, "at several hundred thousand is to give an estimate which those who have been interested in this department of engineering, and who have traveled along the main railroad lines of the country, must pronounce as low." And we are further informed that in some single cities of the Union over five thousand windmills are manufactured, on an average, each year. For those kinds of work in which the power is not required to be constant, but can be taken when it comes—such as pumping and storing water, compressing and storing air, and driving dynamo-machines to charge electrical accumulators—no machines can be cheaper than windmills, and they are efficient enough. American manufacturers have made great improvements in the machines, and their patterns are pronounced much better than the European patterns, and destined to supersede them. Mr. Wolff's treatise is practical and a little literary, for it gives a very

interesting chapter on the "Early History of Windmills." On the practical and economical side it has chapters on "Wind, its Velocity and Pressure"; "The Impulse of Wind on Windmill-Blades"; "Experiments on Windmills"; "The Capacity and Economy of the Windmill"; and "Useful Data in Connection with Windmill Practice"; with full accounts of the various European and American machines.

PROCEEDINGS OF THE UNITED STATES NATIONAL MUSEUM. 1884. Washington: Government Printing-Office. Pp. 661, with Two Plates.

THIS is the seventh volume of the series of papers established in 1878, which the Institution publishes regularly in "signatures," as sixteen pages are accumulated from time to time, in order to present the matter as early as possible to the public. At the end of the year the sheets are gathered up and embodied in a volume. The articles in this series consist, first, of papers published by the scientific corps of the National Museum; and, second, of interesting facts and memoranda from the correspondence of the Smithsonian Institution.

LOCAL INSTITUTIONS OF MARYLAND. By LEWIS W. WILHELM, Ph. D. Baltimore: N. Murray. Pp. 129. Price, $1.

THIS work is a triple number of the series of "Johns Hopkins University Studies in Historical and Political Science." It presents a careful review of the course of growth of the institutions of the Commonwealth in question, including the organization of the land system; the constitution and functions of the hundred; the formation of the county; with the history of the beginnings of each, and the more tardy growth of the towns. In the last section we meet the interesting and suggestive observation, which we quote, that "no student of society can have watched the operations of the vital processes of the social organism and failed to notice the complex growth of certain institutions, and the corresponding decay in authority of officers associated with their development. The brooding, in society, of the spirit of democracy has tended to develop the institution, to multiply its organs, to strengthen its members, and foster its general growth, but at the same time there has been a corresponding contraction of the jurisdiction of its representative officer, and a diffusion of his powers among many associates. When we recall the full meaning of *patria potestas*, we are led to exclaim, 'The fathers, where are they?' and the patriarchs, do they live forever? Quite often the serfs have become the sovereigns, and the sovereign has been reduced to a subject. Could great Augustus have seen the base uses to which the title 'emperor' had been put by barbarians, his heart would have died within him.* And who would recognize in the common hangman, or in the distrainer of house-rents, the sheriff or the constable of the proud Norman court? Could the voice of prophecy have told Charles Martel, who ruled the ruler of the Franks, that his title of major or mayor would descend to administrators of petty villages, he would have had additional reasons for moralizing upon the deceits of human greatness."

REPORT OF THE OPERATIONS OF THE UNITED STATES LIFE-SAVING SERVICE, for the Year ending June 30, 1884. Washington: Government Printing-Office. Pp. 476.

FIVE stations were added during the year, and the number of stations at its close was 201. Of these, 56 were on the Atlantic, 37 on the lakes, seven on the Pacific, and one at the Falls of the Ohio. The whole number of disasters reported was 430, endangering $10,607,940 of property, and the lives of 4,432 persons. Of the persons, all but twenty were saved, and only $1,446,586 of the property was lost. The number of vessels totally lost was 64. The Service has co-operated in scientific movements by assisting investigations in marine zoölogy, and by collecting "singing-sands" for examination by Professor H. C. Bolton. The concluding statement in the summarized report, regarding the character of the Service's men, is very suggestive. It is: "It is felt that seldom in the history of organizations has a body of men been assembled

* Not only did the "sole power of constituting and appointing the *Emperor* of Pascattoway reside with a subject of the English king, the proprietary of Maryland, but the "King of Choptico" was presented for pig-stealing at a court-leet of a Maryland manor.

so equal in qualification for the stern tasks set them, and so splendid in their efficiency. That they can have such a character collectively is clearly attributable to their having been selected for their posts solely on professional and moral grounds, without the slightest reference to their politics. The constant purpose of the officers in charge has ever been to obtain for station duty the ablest and trustiest surfmen. Previous reports of the Service have made apparent how difficult it was, for years, to limit the choice of these agents to the simple tests of their ability and trustworthiness, and how great and absolute a help in this regard has been the statute of 1882, peremptorily exempting the selection from political influences. It can be safely said that in no instance have the requirements of that statute been disregarded, either in spirit or letter."

A CATALOGUE OF SCIENTIFIC AND TECHNICAL PERIODICALS (1665 TO 1882). Together with Chronological Tables and a Library Check-List. By HENRY CARRINGTON BOLTON. Washington: Published by the Smithsonian Institution. Pp. 776.

THE mass of periodical literature has become stupendous; and the real importance it has attained is hardly less striking than its magnitude. The literature in some departments embodied in periodicals has nearly overtaken in value that which has been collected in books, and in the present course and tendencies of publication bids fair, before long, to pass it. In science, especially, is that which is comprehended in periodical publications indispensable to the investigator who would make real progress. A large proportion of the experiments of the past and of the details of results attained can not be given in books, but must always be sought for in the periodicals in which the records first appeared. A perfect index to this literature would lead the inquirer directly to every experiment; but such an index can hardly be hoped for at present, and would be of inconvenient bulk, if it existed. We must take it in parts. In this work Professor Bolton has given a very important part—a list of scientific periodicals, alphabetically arranged, with the cross-references so necessary in every work of the dictionary class; classified according to the subject; with a chronological table showing the date when each volume of each periodical was published; and an alphabetical index to that; and a partial list—as complete as it could be made for the first issue—of the libraries in the United States and Canada where the several periodicals may be found. This catalogue and the "Catalogue of Scientific Serials," published by Mr. Scudder in 1879, complement one another. Mr. Scudder's catalogue includes the transactions of learned societies in the natural, physical, and mathematical sciences, and technical journals only to a limited extent; the present work is confined to scientific and technical "periodicals" proper, excluding society proceedings and transactions, but including periodicals devoted to the "applications" of science. Medicine has been excluded, but anatomy, physiology, and veterinary science, being related to zoölogy, have been admitted. Of the category of included subjects, it contains the principal independent periodicals of all branches published in all countries, from the rise of the literature in question to the close of the year 1882. The effort has been made to give full titles and names of editors. In some debatable cases titles have been admitted, on the ground, as enunciated by Buchold, that "in a bibliography it is much better that a book should be found which is not sought, than that one should be sought for and not found." The cross-references are from the later to the first title of a periodical which has suffered changes in title; from short titles in common use to the accurate designations; from the names of the principal editors to the journals conducted by them; and, in the case of astronomical publications, from the places in which the observatories are situated to the titles of the periodicals issued therefrom. The library check-list has been prepared from the data afforded in the answers to circulars which were sent out to two hundred libraries, of which one hundred and twenty librarians responded. The material for the work was gathered from all available bibliographies, personal examination of the shelves and the catalogues of many libraries in the United States, as well as of important libraries in England, France, and Germany, and from the answers to circulars

sent to publishers asking for specimen numbers of their periodicals. The catalogue includes the titles of five thousand one hundred and five periodicals in the English, German, French, Italian, Spanish, Portuguese, Dutch, Scandinavian, Hungarian, and Slavic languages, of which two thousand one hundred and fifty are placed in the library check-list. Ninety-four subjects are included in the classified list, in which periodicals devoted to general science do not enter. Of these subjects, the most numerously represented is that of agriculture.

GEOLOGICAL AND NATURAL HISTORY SURVEY OF MINNESOTA. By N. H. WINCHELL, State Geologist. First Annual Report, 1872, pp. 112; Tenth do., 1881, pp. 254, with Fifteen Plates; Eleventh do., 1882, pp. 219; Twelfth do., 1883, pp. 387, with Map and Plates.

THE first report includes an historical sketch and list of publications relating to the geology and natural history of Minnesota, beginning with Father Hennepin's book, and a general sketch of the geology of the State. The "tenth report" contains descriptions of about four hundred rock samples and notes on their geological relations, continued from the previous report; a paper on the Potsdam sandstone, papers on the Crustacea of the fresh waters of Minnesota, etc. The "eleventh report" includes a report on the mineralogy of the State; and papers on the crystalline rocks; rock outcrops in Central Minnesota; Lake Agassiz (a large, ancient lake, of which traces are found in an extensive region); the iron region of Northern Minnesota, etc. The "twelfth report" is mainly devoted to paleontology and the fauna and flora.

LIFE OF FRANK BUCKLAND. By his Brother-in-Law, GEORGE C. BOMPAS. Philadelphia: J. B. Lippincott Company. Pp. 433. Price, $2.

FEW men have been privileged to do more to popularize science, as represented in natural history, and to spread abroad love for animals, than the subject of this memoir. His life was very largely devoted to the study of animated nature, to the development of its economical value, and the collection and increase of information on every aspect of it. The objects with which he labored, and the principles by which he was guided are well expressed in the counsel he gave in the first number of "Land and Water," in January, 1866: "Let none," he said, "think himself unable to advance the great cause of natural history. Thousands of Englishmen and Englishwomen have knowledge and experience, acquired by their actual observation of useful facts relating to animated beings, be they beasts, birds, insects, reptiles, fishes, or plants. Friendly controversy and argument are invited on all questions of practical natural history, and although the *odium salmonicum* not unfrequently assumes more virulence than even the *odium theologicum* of the good old days of fagot and stake, no writer need fear that his pet theory shall be ruthlessly set on fire, or that his arguments shall be decapitated, without a fair and friendly hearing." Mr. Bompas has given a very picturesque and engaging story of a man who was certainly one of the liveliest characters in the history of science.

FORESTS AND FORESTRY IN POLAND, LITHUANIA, THE UKRAINE, AND THE BALTIC PROVINCES OF RUSSIA. Compiled by JOHN CROUMBIE BROWN. Edinburgh: Oliver & Boyd; Montreal: Dawson Brothers. Pp. 276.

DR. BROWN follows up his review of the condition of the forests and of forestry in the several countries of Europe with praiseworthy industry and devotion to the cause of reclothing the waste places of the earth. The present volume is like the others of the series which we have noticed in plan and style. It gives accounts of the countries and peoples, and their history so far as it is connected with forestry, and detailed information concerning the present extent, use, and care of the forests.

MAGNETO- AND DYNAMO-ELECTRIC MACHINES; with a Description of Electric Accumulators. From the German of GLASER DE CEW. New York: D. Van Nostrand. Pp. 301.

THIS is the first volume of a new series, called "The Specialist Series," to be edited by Dr. Paget Higgs and Professor Charles Forbes, the purpose of which is to impart information on recent technical subjects in a manner suited to the popular intelligence. Concerning the immediate subject of the

present volume, after noticing the extravagant views that were at first entertained of the machines, the editors say: "Now the dynamo is likely to take a fair stand in the rank of useful machines; for a time it was a machine regarded as likely to revolutionize all the mechanical world; now it is coming to be considered in its true light as a very valuable aid and auxiliary to steam and other prime movers, extending their sphere, and making more easy their application. For these reasons, it is assumed that the public interested in such technical matters are desirous of a more intimate knowledge of the principles of these machines, and this knowledge it is the object of the present hand-book to supply."

LECTURES ON THE SCIENCE AND ART OF EDUCATION, with other Lectures and Essays by the late JOSEPH PAYNE. Reading-Club edition. Syracuse, N. Y.: C. W. Bardeen, publisher. Pp. 281.

AMONG the multitude of books that are teeming from the press on the subject of education, this is one of the soundest and safest, and really the most advanced in its spirit, and in the principles it labors to inculcate. Its editor says in his preface: "It must be remembered that this volume was not prepared by the author as a text-book, but is simply a compilation of addresses and papers delivered at different times and under different circumstances. Hence the same truth is often repeated, not only in different expression, but with different application." Only by an intelligent comparison of these various statements can Professor Payne's views be thoroughly understood; and, for this comparison, these analyses are almost indispensable. The central principle of Professor Payne's system stands out boldly, and is reiterated at every opportunity, that the pupil "knows only what he has discovered for himself, and that in this process of discovery the teacher is only a guide."

He thus closes his masterly lecture on "The True Foundation of Science-Teaching": "I do not for a moment deny that much is to be gained from the study of scientific text-books. It would be absurd to do so. What I do deny is, that the reading-up of books on science—which is, strictly speaking, a literary study—either is or can possibly be a training in scientific method. To receive facts in science on any other authority than that of the facts themselves; to get up the observations, experiments, and comments of others instead of observing, experimenting, and commenting ourselves; to learn definitions, rules, abstract propositions, technicalities, before we personally deal with the facts which lead up to them—all this, whether in literary or scientific education—and especially the latter—is of the essence of cramming, and is therefore entirely opposed to, and destructive of, true mental training and discipline."

LECTURES ON TEACHING, delivered in the University of Cambridge, during the Lent Term, 1880. By J. G. FITCH, M. A., Assistant Commissioner to the late Endowed Schools Commission, and one of her Majesty's Inspectors of Schools. New edition. With a Preface by an American Normal Teacher. New York: Macmillan & Co. 1885. Pp. 393. Price, $1.

WE have previously spoken in emphatic praise of this able educational work, and are glad to see that it has now been brought out in a cheaper edition. Fitch is probably the best authority on general education connected with the English school system. He is thoroughly informed and thoroughly practical, and his book should be in the hands of every teacher who has capacity or liberty to think upon the subject of teaching.

TALKS AFIELD: ABOUT PLANTS AND THE SCIENCE OF PLANTS. By L. H. BAILEY, Jr. Houghton, Mifflin & Co. Pp. 173. Price, $1.

THIS little book has many pictures, and contains many interesting explanations and descriptions of vegetable processes and general plant phenomena. It will interest all who have botanical tastes, and will assist to develop those tastes where they do not exist.

LESSONS IN ELEMENTARY PRACTICAL PHYSICS. By BALFOUR STEWART, F. R. S., and W. W. HALDENGEE. Vol. I. General Physical Processes. Macmillan & Co. Pp. 291. Price, $1.50.

THIS is a manual for the physical laboratory, and is mainly devoted to instruments and apparatus. It deals chiefly with experimental determinations of length, angular measurement, mass, density, elasticity, press-

ure, gravitation, and kindred conceptions, but is to be followed in due course by a volume on "Electricity and Magnetism," and by a third work on "Heat, Light, and Sound." The names of Balfour Stewart, Professor of Physics in the Owens College, Manchester, and of his assistant demonstrator in physics, are sufficient guarantee that the work is thoroughly done.

THE NATURE OF MIND AND HUMAN AUTOMATISM. By MORTON PRINCE, M. D. Philadelphia: J. B. Lippincott Company. Pp. 173. Price, $1.50.

THIS is a closely reasoned discussion of the essential issues of materialism. It first took form several years ago as a graduating medical thesis, which the author did not publish at the time, as he preferred to wait for further reflection and investigation of the subject. It is predominantly polemic, as Dr. Prince finds himself brought into collision with the views of Tyndall, Fiske, Huxley, and Spencer, which he controverts with much acuteness. He ranks himself as a materialist under his own view of what materialism is, and finds himself in more decided harmony with the doctrines of Professor Clifford than with those of any other recent or contemporary thinkers upon this subject. We can not undertake to expound the view of the relations of body and mind which seems to him most rational, but unhesitatingly recommends his work to all who are looking for a vigorous and original treatment of the profound problems to which the volume is devoted.

OUTLINES OF PSYCHOLOGY. Dictations from Lectures by HERMANN LOTZE. Translated, with a chapter on "The Anatomy of the Brain," by C. L. HERRICK. Illustrated. Minneapolis, Minn.: S. M. Williams. Pp. 149, with Plates. Price, $1.25.

MUCH has been said of the claims of Lotze as a philosopher, psychologist, physiologist, etc., and, as his translator here remarks, he "is rapidly gaining recognition even in America." It was time, therefore, that he should be translated, and a good beginning is here made in this little volume. Those who can not read him in the original may now judge of his claims, and get the benefit of his contributions to philosophy.

ON TEACHING: ITS ENDS AND MEANS. By HENRY CALDERWOOD, Professor of Moral Philosophy at the University of Edinburgh. Third edition. Macmillan & Co. Pp. 126. Price, 50 cents.

THIS book emanates from a distinguished source, and, while Professor Calderwood has a recognized prominence as a philosopher, he is also a practical teacher of long experience in every grade, and besides has had much to do with the management of the Edinburgh public schools. It would be unjust to say that his book is without merit; there is much in it that is worth attending to, but it is not of the high grade that we should expect from the position and opportunities of its author. A better book was due from him than any we have on the subject of moral education; but he contributes nothing new or of moment to that most important branch of the art of school management. He seems to be steeped in the pedagogical idea, and is more dominated by the old methods than becomes an original and independent critic of the subject. The first words of his introduction are, "Every one recognizes that a person can teach only what he knows"; but this is so far from being true, that the most successful study may take the form of self-teaching, where the teacher is ignorant of a subject and joins the pupil as a student in pursuing it. Professor Calderwood, however, guards against such an interpretation of his dictum as would imply that instruction is the sole end of teaching; but self-instruction has no such leading place in his system as we think it should have in any rational system of education.

PROPERTIES OF MATTER. By P. G. TAIT, Professor of Natural Philosophy in the University of Edinburgh. Edinburgh: Adam & Charles Black. Pp. 320. Price, $2.25.

THOUGH the name of Black appears upon the title-page of this work as publisher, yet that of Macmillan & Co. is stamped upon the back, and it is announced as one of Macmillan's "Manuals for Students." It is, of course, a good book of its kind, for Tait knows how to do good work. But, though claiming to be an elementary book, it must still be regarded as an advanced text-book, and is intended for students who are "sup-

posed to have a sound knowledge of ordinary geometry and a moderate acquaintance with the elements of algebra and trigonometry." The author adds in his preface, but he (the student) "is also supposed to have—what he can easily obtain from the simple parts of the first two chapters of Thompson & Tait's 'Elements of Natural Philosophy,' or from Clerk Maxwell's excellent little treatise on 'Matter and Motion'—a general acquaintance with the fundamental principles of kinematics of a point and of kinetics of a particle." It was the author's intention to complete his series of text-books by similar volumes on "Dynamics," "Sound," and "Electricity."

THEORY AND PRACTICE OF TEACHING. By Rev. EDWARD THRING. New and revised edition. Cambridge: University Press. Pp. 262. Price, $1.

WE noticed the first edition of this spirited book at the time of its appearance. It is very readable, but full of English views upon the subject, although many of them are as applicable here as anywhere. We are glad to see that it has been amplified and improved.

THIRD BIENNIAL REPORT OF THE BUREAU OF LABOR STATISTICS OF ILLINOIS. 1884. JOHN S. LORD, Secretary. Springfield. Pp. 654.

THE contents of this report are presented in three parts, each of which is devoted to some special line of statistical inquiry on the general topic of industrial affairs in Illinois, and the relations which the different classes engaged in them sustain to each other and to the State. The first part contains an investigation designed to ascertain what proportion of the results of manual labor in manufactures accrues to the proprietor and what to the workman. In part second are presented the results of special investigations made by the bureau into the economical and social condition of the industrial classes of the State; and the third part gives comprehensive statistics of coal-mining and the manufacture of drain-tile in Illinois; with a report on the model industrial community at Pullman, in which are expressed the conclusions reached by a number of representatives from the various State Bureaus of Labor Statistics, after an investigation extending through several days.

PUBLICATIONS RECEIVED.

Progress of Astronomy in the Year 1884, by Professor Edward S. Holden, pp. 55; Progress in Zoölogy in the Year 1884, by Professor Theodore Gill, pp. 98; Progress in Vulcanology and Seismology in the Years 1883, 1884, by Professor Charles G. Rockwood, Jr., pp. 21; Antiquities at Pantaleon, Guatemala, by Lieutenant Charles E. Vreeland, U. S. N., and J. F. Bransford, U. S. N., pp. 12; Papers relating to Anthropology, pp. 38. All from the Smithsonian Report for 1884. Washington: Government Printing-Office. 1885.

Crystallization, by Dr. Persifer Frazer, pp. 11; The Tehuantepec Ship Railway, by E. L. Corthill, C. E., pp. 33. Reprints from the "Journal of the Franklin Institute," Philadelphia. 1885.

Report of a Special Committee of the Franklin Institute on the Efficiency and Duration of Incandescent Electric Lamps. Philadelphia: The Franklin Institute. 1885. Pp. 127.

Publications of the Museum of Comparative Zoölogy of Harvard College, Mass. Pp. 8.

Proceedings of the Illinois State Board of Health. Quarterly Meeting, Chicago, July 2–3, 1885. Pp. 26.

Notes on the Island of Jura, Scotland, pp. 5; and Syenite and Gabbro in Massachusetts, pp. 3. By Dr. M. E. Wadsworth.

An Olivine-bearing Diabase from St. Georges, Maine. By Q. E. Dickerman and M. E. Wadsworth. Pp. 2.

Meteorology of the Mountains and Plains of North America, as affecting the Cattle-growing Industries of the United States. By Silas Burt. St. Louis, Mo. 1885. Pp. 7.

Studies from the Biological Laboratory of Johns Hopkins University. Edited by H. Newell Martin and W. K. Brooks. Vol. III, No. 3. Baltimore: N. Murray. June, 1885. Pp. 72. 75 cents.

Influence of the Proprietors in founding the State of New Jersey. By Austin Scott, Ph. D. Baltimore: N. Murray. August, 1885. Pp. 26.

Niagara Park. Original and Selected Descriptions, Poems, and Adventures, by Various Writers. Edited by Alice Hyneman Rhine. New York: Niagara Publishing Company. 1885. Pp. 112. Illustrated. 50 cents.

A Canterbury Pilgrimage, Ridden, Written, and Illustrated, by Joseph and Elizabeth Robins Pennell. New York: Charles Scribner's Sons. 1885. Pp. 78. 50 cents.

Creation. Man's Fall explained in the Light of Modern Science. New York: Lawrence S. Benson. 1885. Pp. 15. 15 cents.

The Modification of Plants by Climate. By A. A. Crozier, Ann Arbor, Mich.: The Author. 1885. Pp. 35. 25 cents.

The Song Budget, for Schools and Educational Gatherings. Compiled by E. V. De Graff, A. M. Syracuse, N. Y.: C. W. Bardeen. 1885. Pp. 76. 15 cents.

"The Black Diamond." Published in the interest of the coal-trade industry. F. S. Jervis and H. A. Bischoff, Editors. Chicago: The National Coal Exchange. Monthly. Pp. 12. $1 a year.

"The Hoosier Naturalist." A. C. Jones, R. B. Trouslot, Editors and Publishers. Valparaiso, Ind. Monthly. Pp. 8. 50 cents a year.

Bulletin of the Museum of Comparative Zoölogy of Harvard College. Vol. XII, No. 1. Chlamydoselachus Anguineus Garm—A Living Species of Cladodont Stork. By S. Garman. Cambridge. 1885. Pp. 35, and numerous Plates.

The Utilization of the Sun's Rays in heating and ventilating Apartments. By Professor E. S. Morse. Pp. 8.

The Attraction and the Figure of Equilibrium of a Rotating Fluid Mass and the Interior Density and Temperature of the Earth. By D. P. Blackstone. Madison, Wis. 1885. Pp. 58.

Fiat Money. A Review of the Decisions of the

United States Supreme Court as to its Constitutionality. By Francis A. Brooks. Boston: Little, Brown & Co. 1885. Pp. 28.

Sanitary Engineering. A Course of Study recently established at the School of Mines of Columbia College, New York.

Sibley College, Cornell University, Schools of Mechanical Engineering and Mechanic Arts. 1885.

A Memoir of Charles Hilton Fogge, M. D. Philadelphia: P. Blakiston, Son & Co. Pp. 7.

The Relation of Annual Rings of Exogens to Age. By D. P. Penhallow. From the "Canadian Record of Science." 1885. Pp. 14.

Valdimir. A Poem of the Snow. New York: H. Lockwood. 1885. Pp. 46. 25 cents.

Second Annual Report of the State Agricultural Experiment Station at Amherst, Mass. 1884. Boston: Wright & Potter. 1885. Pp. 166.

Transactions of the Sixteenth and Seventeenth Annual Meetings of the Kansas Academy of Sciences, with the Report of the Secretary. Vol. IX. Topeka: T. D. Thatcher. 1885. Pp. 146.

Success in Life physiologically considered. By James T. Seavey, M. D. Tuscaloosa, Ala. Pp. 39.

Possibility of Errors in Scientific Researches due to Thought Transference. By E. C. Pickering. From Proceedings of American Society for Psychical Research. Pp. 43.

Contributions to our Knowledge of Sewage. By William Ripley Nichols and C. R. Allen. Pp. 6.

"The Sun." A bi-monthly publication devoted to Coöperation. Vol. I, No. 1. Subject: Prohibition. Kansas City, Mo. C. T. Fowler. Pp. 28. 10 cents.

The Story of Manitou. Denver, Col. S. K. Hooper. Pp. 64. Illustrated.

"The Journal of Physiology." Vol. VI, Nos. 4 and 5. Cambridge Scientific Instrument Company. July, 1885.

The Minting of Gold and Silver, pp. 20; and Placer Mines and Mining Ditches, pp. 64. By Albert Williams, Jr. From the Report of the Tenth Census of the United States.

Zoölogic Whist and Zoönomia. Representing the Orders of the Animal Kingdom. By Hyland C. Kirk. New York: McLoughlin Bros. 1885. $1.

Philosophic Series: No. I, Criteria of Diverse Kinds of Truth as Opposed to Agnosticism, pp. 60; No. II, Energy, Efficient and Final Cause, pp. 55; No. III, Development, what it can do and what it can not do, pp. 50; No. IV, Certitude, Providence, and Prayer, pp. 46; No. V, Locke's Theory of Knowledge with a Notice of Berkeley, pp. 77; No. VI, Agnosticism of Hume and Huxley, with a Notice of the Scottish School, pp. 70; No. VII, A Criticism of the Critical Philosophy, pp. 60; No. VIII, Herbert Spencer's Philosophy as Culminated in his Ethics, pp. 71. By James McCosh, D. D., LL. D., D. L., President of Princeton College, etc. New York: Charles Scribner's Sons. 1883–1885.

The America's Cup. How it was won by the Yacht America in 1851, and has been since defended. By Captain Roland F. Coffin. New York: Charles Scribner's Sons. 1885. Pp. 155. $1.

Lawn Tennis as a Game of Skill. By Lieutenant S. C. F. Peile, M. S. C. Edited by Richard D. Sears. New York: Charles Scribner's Sons. 1885. Pp. 90. 75 cents.

The Student's Manual of Exercises for translating into German. By A. Lodemon, A. M. New York and London: G. P. Putnam's Sons. 1885. Pp. 87. 50 cents.

Chemical Problems. By Dr. Karl Stammer. From the German, by W. S. Hoskinson, A. M. Philadelphia: P. Blakiston, Son & Co. 1885. Pp. 112. 75 cents.

Ballooning. A Concise Sketch of its History and Principles. By G. May. New York: D. Van Nostrand. 1885. Pp. 94.

The Chronicle Fire-Tables for 1885. A Record of the Fire-Losses in the United States, by Risks, States, and Causes during 1885, with Exhibits of the Monthly, Annual, and Aggregate Fire-Losses in the United States and Canada during the Years 1875–1884. New York: "The Chronicle." 1885. Pp. 150.

Barbara Heathcote's Trial. A Novel. By Rosa Nouchette Carey. Philadelphia: J. B. Lippincott Company. 1885. Pp. 303. 50 cents.

The Will. A Novel. By Ernst Eckstein. From the German, by Clara Bell. New York: W. S. Gottsberger. 1885. 2 vols. $1.75.

Modern Molding and Pattern-Making. By Joseph H. Mullin, M. E. New York: D. Van Nostrand. 1885. Pp. 257.

Malthus and his Work. By Joseph Bonar, M. A. London: Macmillan & Co. 1885. Pp. 432. $4.

Annual Report of the Board of Regents of the Smithsonian Institution for 1883. Washington: Government Printing-Office. 1885. Pp. 959.

Paleontology of the Eureka District. By Charles Doolittle Walcott. Vol. VIII. Monographs of the United States Geological Survey. Washington: Government Printing-Office. 1885. Pp. 298, and Twenty-four Plates.

POPULAR MISCELLANY.

Malaria and the Eucalyptus.—The experiment of preventing malaria by plantations of eucalyptus-trees at Tre Fontaine, near Rome, has failed. While the eucalyptus-trees thrive, the malaria continues. Fevers prevailed there in 1880, and even during the season, exceptionally healthy at Rome, of 1882, and under circumstances which made the epidemic seem largely local. A government commission has been appointed to examine into the matter, on the application of Professor Tommasi-Crudelli, who suggests that, until the inquiry is completed, conjectures as to the cause of the visitation be abstained from. The facts are, however, he says, practically instructive, "proving as they do once more to what risks of mistake we expose ourselves if we hold *a priori* that the methods which have resulted in a permanent improvement of one malarious locality can be usefully applied to all. The condition of permanent improvement is that of so modifying the physical conditions and the chemical composition of the soil as to render it incapable of producing the malarial ferment. If all malarious soils were similarly situated and had the same chemical composition, we should be certain of obtaining a permanent improvement in them by the adoption of a system of cultivation by which this result has been brought about in any one of them; but, unfortunately, malaria is produced in soils whose situation and chemical composi-

tion are most various, so that the system by which some have been improved may fail entirely when applied to others. So with the plantations of eucalyptus, they succeed in one place and not in others. We know nothing precisely about the nature of the cultivation which should be adopted in order to produce in a given species of malarious soil a final modification of its physical conditions and chemical composition which shall render it incapable of producing the poisonous ferment. At present we are feeling our way, with the result that often we obtain useful results by means of high cultivation, and as often not." Dr. Tommasi-Crudelli recommends arsenious acid and the alkaline arseniates as the most efficient protective agents against malaria.

Changes at Niagara Falls.—A reference to the earliest published accurate account of Niagara Falls—that of Kalm, the Swedish traveler, in the "Gentleman's Magazine" for January, 1751—shows that changes are going on there more rapidly and on a grander scale than has been estimated. Kalm describes a fall of one hundred and thirty-seven feet, with "a series of smaller falls, one under another," for two and a half leagues below. Much of this series has now disappeared, and the main fall has been raised to one hundred and sixty feet. He describes the horseshoe as only slightly concave, and adds: "Above the fall, in the middle of the river, is an island, lying also south-south-east and north-northwest, or parallel with the sides of the river; its length is about seven or eight French arpents (an arpent being one hundred and twenty feet). The lower end of this island is just at the perpendicular edge of the fall. . . . The breadth of the island at its lower end is two thirds of an arpent (eighty feet) or thereabout." This can not be Goat Island, which is ten times as large, but must refer to Luna Island, which, if the description is correct, has been greatly reduced since it was written. Goat Island appears not to have been touched by the falls at that time.

Social Life in Masai Land.—Mr. Joseph Thomson states that the most remarkable distinctions characterize the various epochs in the life-history of the Masai people of East Africa. The boys and girls up to a certain age live with their parents, and feed upon meat, grain, and curdled milk. At the age of twelve with the girls and between twelve and fourteen years with the boys, they are sent from the married men's kraal to one in which there are only young unmarried men and women. There they live in a very indescribable manner till they are married. At this stage the men are warriors, and their sole occupation is "cattle-lifting" abroad and amusing themselves at home; the young women attend to the cattle, build the huts, and perform other necessary household duties. Both sexes are on the strictest diet. Absolutely nothing but meat and milk passes their lips. Spirits and beer, tobacco, and vegetable food, are alike eschewed. So peculiar, indeed, are they in their notions, that they will not even eat the meat of any wild animal. Moreover, the meat and milk are never taken together. For several days the one is their sole diet, to be followed by the other after partaking of a powerful purgative. On killing a bullock, they drink the blood raw, which doubtless supplies them with the necessary salts. In eating meat they always retire to the forest in small parties accompanied by a young woman. So pleasant does the Masai warrior find this life that he seldom marries till he has passed his prime, and begins to find his strength decline. The great war-spear and heavy buffalo-hide shield, the sword and the knob-kerry, are then laid aside. For a month he dons the dress of an unmarried woman, and thereafter becomes a staid and respectable member of Masai society. He goes no more to war, but devotes himself to the rearing of a brood of young warriors. His diet changes with his mode of life, and he may indulge in vegetable food, drink beer or spirits, and smoke or chew tobacco. At death, the body is simply thrown out to the hyenas and vultures.

Underground Wires and Atmospheric Electricity.—M. Blavier remarks, in a note to the French Academy of Sciences, that while it is only in exceptional cases that the influence of storms is observed on underground telegraphic lines, there are nevertheless sometimes produced, in offices connected

by underground wires, electric discharges which fuse the fine wires of the lightning-guards. These accidents are much less frequent and less severe than in the cases where the wires are aërial, and they do not seem to be of such a nature as to interfere with the transmission of dispatches. They correspond always to storms which occur in the country, at some distance from towns where the underground wires are protected by the net of water and gas pipes below which they are placed. If the wire is buried only at a slight depth in a badly conductive soil, the coating, under the influence of storm-clouds, takes a more or less considerable electric charge, even when the internal wire remains in a neutral condition. At the moment when the lightning flashes, this charge is suddenly liberated, at least in part, and escapes into the earth, following the metallic coating in two opposite directions.

Coal-Dust and Mine-Explosions.—We have already given an account of the experiments of the Prussian Fire-Damp Commission at Neunkirchen, with reference to explosions in coal-mines, and of the conclusion of Mr. W. Galloway, from the observation of some of them, that the explosions are chiefly or very largely promoted by coal-dust. A French commission has reported upon this subject that they consider it established that "coal-dust in the absence of fire-damp does not constitute an element of danger," although it may play an important part in aggravating the consequences of an explosion. Mr. Galloway is now able to cite, in support of his view of the importance of the agency of coal-dust, the expression of Herr Hilt, in the official preliminary report of the Prussian commission, who, speaking of the dust from Pluto mine, in Westphalia, says that "there can be no doubt that with this kind of dust the flame could be lengthened out to any desired extent, provided the gallery and the layer of dust on its floor were made equally long;" also the statement that "the dust of New Iserlohn behaves in the same way." Mr. Galloway further cites a table of dusts of different degrees of fineness, published in the same report, to show that the explosive property of coal-dust increases with its fineness. He believes that the French commission were not accurate or thoroughgoing enough in their experiments. We mention also, as bearing on this subject, and going to confirm Mr. Galloway's views, that the Clifton Hall colliery, near Manchester, England, where a fatal explosion occurred in June last, was at the time dry and dusty, and very free from fire-damp.

Mutilations of the Teeth.—The practice of filing the teeth is still in vogue among the Mohammedan Malays. The individual may choose, according to his fancy, among three fashions: that of simply rubbing away the front surface of the tooth; that of filing away the sides so as to leave the front of the tooth standing out in a triangular relief; and a sharpening of the tooth—for all of which styles considerable variety in patterns exists. As all the Mohammedan islanders set much store on having their teeth properly "improved," the tooth-filer is an important personage among them. His outfit includes a hammer, a bracing-stone or anvil, chisels, files, and saws. The person to be operated upon prepares his teeth for the purpose by chewing raw rice and turmeric, and, prostrating himself on the ground, lays his head, blindfolded, upon the operating-bench. The operator demonstratively repeats an unintelligible incantation phrase, and, wedging the subject's mouth open, performs his work. The filing done, the teeth are blackened, and the pain is quieted with cocoanut-water in which an iron, inserted red-hot, has been standing for several days. For some time after the operation, the patient must avoid eating things unpleasant to sore teeth. As a recompense, he has come into full credit in society, and may marry. The legendary origin of the custom is a miraculous escape Mohammed is said to have once had from the pursuit of a redoubtable antagonist. After having eluded his pursuer by being overshadowed by a swarm of bees, he was nearly overtaken again, and hid in a dry well. Some of the pursuing party thought he might be in the well, and threw stones into it. He was looking up at the time, and the stones knocked out four of his upper teeth. The fashion of filing down the teeth is, however, probably older than Mohammedanism. M. E. T. Hamy has made a study of

the perforations of the teeth by the aborigines of Central America and Yucatan which are mentioned by various authors. Mota Padilla says the Indians cut their teeth down to sharp points and bored holes in them, which they filled with a black cement. A statuette dug up at Téjar has the upper front teeth thus bored with cylindrical holes; and a fragment of an upper jaw dug up at Campeachy, during the French occupation, shows the real teeth marked with precisely similar perforations. The holes appear to have been filled afterward with bluish-green stones. The operation of boring these holes can hardly have been practiced on living persons, and the evidence indicates that it was done after death. No similar mutilations are known to be practiced now anywhere.

Increase of Temperature in Tunnels.—Professor G. A. Koch, of Vienna, has been prompted, by the experience of the workmen in the St. Gothard Tunnel, to make researches into the phenomenon of increase of temperature which is observed in excavating under mountains. Dr. F. M. Stapff, geologist of the St. Gothard Railway, had already published a paper covering the questions of the highest temperature at which it is possible for men to work in subterranean galleries, and the depth under the mountain-mass at which this temperature is reached. Assuming that work begins to be dangerous at the temperature of the blood, 98° Fahr., and that the limits of the vital endurance in animals lie between the temperature at which albumen thickens (60° C., or 140° Fahr.) and that at which it coagulates (75° C., or 167° Fahr.), he deduced that in an extremely dry atmosphere men may keep at work at 50° C. (122° Fahr.), while labor would be impossible at such a temperature in an atmosphere saturated with moisture. The answer to the other question is difficult, because the conditions vary. Descending into the earth from a level surface, the temperature increases at the rate of about 1° C., or 1·8° Fahr., for every thirty-three metres in depth; but the rates fluctuate greatly when the surface is a mountain and the excavation is horizontal, and are governed not only by the height of the overlying mountain above the crown of the tunnel, but also by what is the shortest distance between any point of the tunnel and the nearest point on the surface of the mountain. In the Mont Cenis Tunnel the highest temperature in the stone (29·05° C., or 85° Fahr.) was reached at a depth of 1,607 metres and a distance of 6,448 metres from the southern portal, indicating an increase of about a centigrade degree for every fifty metres. Other observations give rates ranging from 1° C. in twenty-four to 1° in fifty-one metres, and an average of 1° in 37·75 metres, the variations being governed by local influences as well as by the form of the surface. The operation of local influences was very plainly observed in the St. Gothard Tunnel, where abundant evidence was gathered that the temperature curves are greatly distorted under mountain-peaks. The average rate of increase in the St. Gothard Tunnel, according to Dr. Stapff, was 1° C. to 48·4 metres; but this rate was considerably exceeded under the valleys and the plain surfaces, while it was greater than the increase observed under the crests of the mountains. The temperature of the spring-water must evidently conform to the general law of increase. Dr. Stapff observed that the tunnel-water is cooler than the stone when the temperature is less than 24° or 25° C., but warmer than the stone at above 25°; and a prediction which he based on this observation, that springs of a decidedly unpleasant temperature would be met at a certain point in the excavation, was fulfilled to the letter. The fact is an important one, in view of the impossibility of working in a moist and hot atmosphere. The temperature of the air in tunnels is also affected by similar laws, and some very curious facts bearing on this point were noticed in the St. Gothard Tunnel. To the natural increase of temperature in the advance of the excavation must be added the additional heating from the men and animals at work, and from the lights and the explosions, which considerably increased the difficulties in some parts of the excavation. All these things must be taken account of in forming the plans of tunnels and estimating their cost; for the expense of labor must be increased in such places, in proportion as it becomes more difficult and dangerous. If these principles are cor-

rectly worked out, we have to draw the conclusion that not all the projected great tunnels are practicable. Dr. Stapff calculates that the Simplon Tunnel, as projected by Favre and Clo, will develop temperatures of 46·9° C. in the stone, 45·85° in the air, and 54·3° in the water, which will be unendurable unless the air is perfectly dry. A shorter tunnel, projected by Clo, Varetz, and Jacquemin, will be more feasible. A projected tunnel under Mont Blanc will probably have to be made in an extreme temperature of 51° C., and this will be impossible. It follows from these observations that while we may generally be able to overcome the difficulties imposed in tunnel-making by length and geological structure, we are not always competent to contend against those imposed by temperature.

Interesting Finds in Pompeii.—In entering Pompeii, says a recent visitor, writing in "Chambers's Journal," "we descend a sloping path to the silent city, which stands between two enormous embankments of ashes, like a very deep railway-cutting, and enter by the great gateway, with arches and pillars in perfect preservation. Through a small arch at the side, intended for foot-passengers, we pass into the deserted streets; from the high, narrow footway we see the tracks of wheels on the paved street below; and the great stepping-stones are still there, as in the days of old. Everywhere stand the remains of sculptured fountains—at the street corners, in every house, in every square. A number of converging streets lead into the Forum. Here are the perfect remains of beautiful temples with their marble columns and sculptured altars, on which the inscriptions may still be read. On some are delicate carvings representing sacrifice, in high-relief, with every detail clear and sharp as when first chiseled. We go through the street of the soap-makers and visit the large soap-works, where the huge iron caldrons are still left. Another street is full of wine-shops, with the large red jars still inserted in the marble counters. Then we pass the city bake-houses, where ovens were found full of charred bread, which is now in the Naples Museum, the baker's name stamped upon each loaf. Close by are the splendid public baths, with every appliance for hot, cold, and vapor baths, the pipes and cisterns still remaining. Near the entrance-gate is a small museum containing the skeletons found in the city—a mother and daughter clasped in each other's arms; a sentinel found at his post; a man evidently knocked down by the cloud of ashes; and several others. Some of them have been injured in the process of excavation. When a skeleton is found, hot plaster-of-Paris is immediately poured into it, so that while preserving the skeleton intact, it gives also, by filling up the impression or mold of the body that had lain there, the form and features of the living man. A large collection of surgical instruments greatly interested a celebrated physician who was one of our party, and who expressed unbounded surprise at the very slight difference between these relics of the infancy of medical science and the instruments in use at the present day. Some large cases of dentists' tools caught our eye also. . . . A great number of paint-boxes are displayed, which still contain the same bright, soft colors that we see on the walls of Pompeii; and case after case of jewels, some found in the house, others evidently dropped in hurried flight from the burning city, or fallen from the necks and arms of the skeletons."

Life on Coral Islands.—The Chagos Archipelago, the southernmost island of which, Diego Garcia, has been made a coaling-station for steamers, may be taken as typical examples of coral islands. Diego Garcia is nearly in the longitude of Bombay, and 7° south of the equator. It is an island of the "atoll" type, fully thirty miles in circumference—"a lake with a shore and nothing else." The shore, in some places a few feet, in others a few yards, but never so much as a quarter of a mile wide, is entirely covered with trees, which are chiefly cocoanut-trees, with various kinds of tree-ferns, and a few flowering shrubs. The archipelago consists of several groups, among which are the Six Islands, which lie in a ring, and are linked together by coral reefs that approach the surface of the sea, but do not rise above it. South of these is the Pitt Bank, a very dangerous atoll, that nowhere rises above high-water mark, and near it some thirty islands,

and at least an equal number of banks, and rocks, and shoals, and reefs, all of the same coral formation. There is often a difficulty in distinguishing one atoll from another. A ring of coral surrounds a lagoon, the entrance to which is on the northwest side. Where the coral is a foot or two above the tide, a thick, green robe of clematis covers the white rock, and tall palms flourish overhead. Outside, the sea is in most cases at least two hundred fathoms deep, and inside it varies from three fathoms in some atolls to an almost unfathomable depth in others. Diego Garcia is situated in one of the hottest places in the world, where fierce sunshine alternates daily with heavy showers, and the temperature is between 80°and 90° all the year round. For scenery, there are the three million palms and the varying blue of the inland sea. The island furnishes, in the names of its several points, suggestions for a romance like that of "Paul and Virginia." "But all such tales fail, in leaving out the realities. There is nothing about fleas in any of them; nothing, or very little, about centipeds. The misery of life on a coral island can hardly be exaggerated. . . . It rains every day. The mosquitoes are unequaled for size and ferocity. The only food is an occasional fresh fish, with tinned meat and vegetables from England. The monotony of existence is only broken by the visit of an occasional ship, or by a gale, which unroofs the house. To the lonely inhabitants it is nothing that beautiful shells and branching coral are to be found on the beach; that strange, bright birds come across the ocean to build their nests in the cocoanut-trees, or that the sea over the reef is an ethereal blue such as no one can imagine who has not seen it."

Restoration of Life. — Dr. Richardson has started the question whether life may not be restored after actual death, and relates some facts that point to the answer as being in the affirmative. By combining artificial circulation with artificial respiration, a dog was restored to life an hour and five minutes after having been killed by an overdose of chloroform, when the heart had become perfectly still and cold, and was passing into rigidity. Animals that have been killed by suffocation and partially dissected were brought to such a state of muscular irritability that the experiment was stopped for fear that they would return to conscious sentient life. Frogs poisoned by nitrate of amyl were restored after nine days of apparent death, in one case after signs of putrefactive change had commenced. The action of peroxide of hydrogen in reanimating the blood and restoring heat in a really dead body is quite startling. From these observations, Mr. W. Mattieu Williams thinks the conclusion is justified that "a drowned or suffocated man is not hopelessly dead so long as the bodily organs remain uninjured by violence or disease, and the blood remains sufficiently liquid to be set in motion artificially and supplied with a little oxygen to start the chemical movements of life."

Peat-Smoke as an Antiseptic. — Dr. Morgan, of Manchester, England, has remarked upon the healthy condition of the Highland crofters, who live in "bothies" the atmosphere of which is impregnated with peat-smoke, and are yet not troubled by disease, being particularly free from consumption and other lung infections. Their rooms are warmed by a peat-fire kept constantly burning in the middle of the floor; and, there being no means of escape for the smoke except a hole in the corner of the roof, the atmosphere is often pungent enough to make the eyes and nostrils smart. Yet the inhabitants are well and vigorous, and are liable to lung-diseases only when they go to live in houses with chimneys. The explanation of the phenomenon is not hard to find. Peat-smoke is heavily charged with antiseptics—with tar, creosote, tannin, and various volatile oils and resins—and the salutary influence of these more than makes up for the adulteration of the air.

Blondes and Brunettes.—Reports have been published of the "complexion-censuses" of the school-children of Germany, Belgium, Cisleithan Austria, and Switzerland. They show that more than one half of those enumerated are of mixed type. The distribution of the pure types—blondes and brunettes—is very different in different countries. The blondes predominate in Belgium, and still more in Germany, while

the brunettes predominate in Austria, and in Switzerland with greater disparity. The predominance of fair complexions in Germany is greatest in the north, and grows less and less in going to the south. This appears to show the incorrectness of the theory of the French anthropologists that we must seek the real Germans in South Germany, and that North Germans are a dark race, a mixture of Finns and Slavs. The deep-brown color of the south and middle Germans, as well as of the Swiss, is traced by Herr Virchow to the Romans, Rhætians, and Illyrians, and especially to the remnants of the Celtic or pre-Celtic inhabitants, which have now become mixed with the Germans.

Contraction of Plant-Tissues by Cold.—Mr. Thomas Meehan has reported some observations which contradict the prevalent idea that the sap in vegetable tissues expands in freezing, and is capable of bursting the organs. Of a number of vigorous trees measured at temperatures of 40° and at 10° above zero, none showed any sign of expansion, but one, a large maple, appeared to have contracted a half-inch. In hardy succulents, including several plants of the cactus family, live-forevers, and stone-crops, a marked contraction was observed; and opuntias showed no traces of congelation at 10°, and were as easily cut with a penknife as at a normal temperature. Plants which contract so much as to shrivel in the cold expand again after a few days of temperature above the freezing-point. Expansion under freezing, however, was evident in dead wood soaked with water; and the bursting of trees, which has been noticed, may result from the freezing of liquid in the less vital parts of their trunks. Assuming, from the facts brought forward, that the liquid in plants which are known to endure frost without injury does not congeal, a question arises as to what power they owe their successful resistance. It is probably a vital power, for the sap of plants, after it is drawn from the tree, congeals easily.

Celtic Superstitions.—Many primitive superstitions of great interest to the anthropologist still linger among the Celtic populations of the British Islands. "The Celt," says a writer who has made much study of his character, "has turned everything to supernatural uses; and every object of Nature, even the unreasoning dream of sleep, is a mirror which flashes back death upon him." Yet these people have nearly lost the fear of death, and it is a common salutation to wish one a decorous and peaceful departure. The ancient Gaels and Cymri believed in intercourse with fairies, whom they called by any other name than their own; hence, the designation of "the men of peace," "the hunters in green," "the good people," etc. Their aversion to naming these beings was greater on Friday than at any other time, for on that day their powers were greatly increased. To wear their favorite color, green, was an unpardonable insult. Rites of a complex nature were gone through to protect the unbaptized infant and its mother from their clutches. Stories were often current of persons who had been detained by fairies for many years. The urisks were a sort of intermediary race between spirits and mortals; if kindly treated, they might render service to the family to which they had joined themselves. Witches were consulted and believed in in Wales so lately as 1826. The Cymri also had their giant, the good Foulkes Ty Du, who was always helping them; but, when evil was about to overtake them, the Tybiath, or presentiment, foreboded it. The Highlanders put great faith in messages from the unseen; and a hundred little incidents, which others would let pass unheeded, are for them fraught with the most solemn meaning. The cock which crows at midnight conveys the intelligence of a death in the neighborhood. Itching of the nose or ringing in the ears bears the same message. If the Highlander's cattle die, the evil-eye has gazed upon them. The boat that drifts empty out to sea has been pushed from its moorings by the fairies.

A Chinese View of Epilepsy.—In China, it is said, when a man is seized with an epileptic fit, those about him rush away for a few blades of grass, which they put into his mouth. They believe that during an attack of this kind the spirit leaves the body, and, there being a vacancy within, it is immediately occupied by the spirit of an animal,

generally a sheep or a pig, and the sound in the person's throat, as he begins to revive, is taken for the bleating of the one or the grunting of the other. Under these circumstances, they attempt to propitiate the animal by putting grass into the man's mouth, possibly under the impression that they can entice the animal's spirit in the man to remain till his own returns; and on no consideration will they remove him till the fit is over, for, if they did, they believe his own spirit would not be able to find him again, and he would die.

NOTES.

THE American Association, recently in session at Ann Arbor, Michigan, elected the following officers for next year's meeting: President, E. S. Morse, Salem, Massachusetts; Vice-Presidents, J. W. Gibbs, New Haven, Connecticut; C. F. Brackett, Princeton, New Jersey; H. W. Wiley, Washington, D. C.; O. Chanute, Kansas City, Missouri; T. C. Chamberlin, Washington, D. C; H. P. Bowditch, Boston, Massachusetts; Horatio Hale, Clinton, Ontario; Joseph Cummings, Evanston, Illinois; Permanent Secretary, F. W. Putnam, Cambridge, Massachusetts (holding over); General Secretary, S. G. Williams, Ithaca, New York; Assistant Secretary, W. H. Pettee, Ann Arbor, Michigan; Treasurer, William Lilly, Mauch Chunk, Pennsylvania. Buffalo, New York, was selected as the place for holding the meeting in 1886.

M. TACCHINI mentioned to the French Academy of Sciences, July 27th, that red sunsets, like those of 1883–'84, though less intense, had appeared again; and said that the present phenomena could not be connected with the eruption of Krakatoa. At the same session of the Academy, M. Janssen read a paper by M. Landerer on the reappearance of the glows. This author thought them of cosmical origin, and suggested that they might be caused by the passage of Biela's comet.

PROFESSOR PETER T. AUSTEN has investigated the relation of aluminic and ferric salts to plant-life. He finds that these salts have the property of precipitating dissolved organic matters, and causing the coagulation of suspended inorganic matters. The substances thus deposited are of high value as plant-food, and are placed in the most available state and most assimilable condition. "Thus we see that when the soil is unable directly to bind the plant nutriment, the acid products of the death of the plant, and probably also of the bacterial fermentations, supply agents which precipitate these plant-foods in such a state that mere mechanical filtration will remove them, and leave them stored up for future use by the plants." These processes also serve animal life by purifying the water.

DR. R. HARVEY REED, of Mansfield, Ohio, after a study of the subject as it affects his own State, concludes that among the results of the destruction of the forests and the drainage of the land are more wind, more humidity, more rainfall, more dust, more sudden dashes of rain; more sudden changes from one extreme to the other of temperature and moisture; more rapid transmission of water from the periphery to the great basins; robbery of the natural regulators of distribution; and diminution of the common supply of springs and wells. These changes have been followed by a decrease of all forms of malarial diseases, and an increase of typhoid fever, catarrh, deafness, and chronic pulmonary troubles, and the increase in wind and dust favors the spread of zymotic and contagious diseases.

A CORRESPONDENT, noticing our reference in a recent sketch of M. Chevreul to the discrepancy in the age of the distinguished chemist's father at his death, as given in Larousse's "Cyclopædia" (ninety-one years), and by the "Lancet" (one hundred and ten years), calls attention to another equally curious mistake respecting M. Chevreul in Schaedler's "Technologie der Fette und Oele." In the historical introduction to this work occurs a passage which we translate thus: "Only thirty years after the discovery of glycerine, in the year 1813, began the researches of Chevreul (born 1786, at Angers, died 1840)." On page 1105, the author appends the correction: "The information was given me privately that Chevreul died in 1840; but I have received from M. J. Bang, of Marseilles, under date of May 11, 1883, the following literal statement: 'I can assure you that Chevreul is still very active, and continues his course at the Museum, and is present every Monday at the Academy of Sciences. He is now ninety-seven and a half years old, but is, they say, livelier than ever.'"

THE authorities of Albany, Georgia, have efficiently drained a troublesome pond by boring a well-hole through the ground to a deep subterranean stream. An outlet for the sewerage of a large Western university has been found in one of the numerous "sink-holes" with which the cavernous limestone of the country is marked, where a similar underground stream carries the stuff to parts unknown. Such expedients are good, provided the subterranean stream selected for the sewer-outlet is not a source of supply for some well.

THE State Board of Health of Massachusetts continues to follow up the use of arsenic in manufactures under all its disguises. They still find the poison in dangerous proportions in papers of various colors, particularly in the glazed papers of fancy boxes, cornucopias, confectionery-boxes, etc., concert tickets, and playing-cards, and in children's toys and articles of clothing. "German fly-paper" is soaked in arsenite of sodium, and is dangerous in more ways than one. The "Buffalo Carpet Moth Annihilator" contains 6·726 per cent of crystals of white arsenic, and "Rough on Rats" contains white arsenic crystals.

PAPER bedclothes are made at a factory in New Jersey. They are doubled sheets of manila paper, strengthened with twine, and valuable by reason of the peculiar properties of paper as a non-conductor of heat. They have a warmth-preserving power far out of proportion to their thickness and weight.

THE Swedish papers report that a crane was shot at Orkened, in Scania, on the 19th of June, which bore a card containing the verse—

"I come from the burning sand,
From Soodan, the murderers' land,
Where they told the lie
That Gordon would die."

The bird had previously been wounded in the wing, and was much exhausted.

THE Aberdeen (Scotland) "Journal" records a remarkable instance of the effect of atmospheric influences on the visibility of lights at night. In March, 1885, the captain of the steamer City of Aberdeen saw the Girdleness light in Aberdeen Bay, at the distance of more than thirty-six miles, and the Buchan-Ness light when it was thirty-two miles off. The distances at which these lights are considered ordinarily visible are nineteen and seventeen miles respectively.

THE "Lancet" publishes a list of facts to show the dangerous character of foot-ball. In its casual examinations of the papers, it has, without making special search for them, recorded some dozen or more instances of serious accidents—in which bones were broken—one of which resulted in death, that occurred in the course of games. While the "Lancet" thinks it would be unwise and undesirable to abolish the game, which is the principal winter amusement of thousands of young people, it calls for a reform in the rules and practice, with such regulations as will reduce the number and severity of accidents, which, being secured, it believes the sport is capable of far more good than harm.

M. J. C. HOUZEAU, in examining some old astronomical manuscripts at Brussels, has met the works of three Belgian astronomers whose names were previously unknown. Henry Selder observed at Tournai in the fourteenth century. In 1340 he had compared Ptolemy's catalogue of the stars with the sky, to ascertain what stars had disappeared and what changed magnitude since the catalogue was compiled. He also compiled a second series of observations in 1367. Eustache de Eldris, who styled himself an astronomer of Liége, made tables of the planets; and Henri of Malines wrote a treatise on astrology.

MR. R. A. MULLAN, an Irish solicitor, mentions the singular observation during a hailstorm in County Down, that some of the hailstones—perhaps one in a hundred—were of a decided red color. Taking up some of them, he found that the color was not merely superficial, but pervaded the substance of the hailstones, and, on melting, they stained his fingers.

OBITUARY NOTES.

MR. N. W. POSTHUMUS, Director of the Higher Burgher School, at Amsterdam, who died recently, was one of the founders of the Dutch Geographical Society, its secretary from the beginning, and one of the editors of its journal. He was forty-seven years old.

DR. BARIUS, surgeon-general to the French army in Tonquin, died in Haiphong June 10th. He was known to the scientific world by his meteorological writings, of which the principal essay embodied his researches on the climate of the Senegal. He kept a regular series of observations at Haiphong.

DR. EMIL RIEBECK, a distinguished traveler, recently died suddenly at Feldkirch, Germany, where he was preparing for a five years' journey. Besides being a traveler himself, he was a liberal patron of explorers. He had borne the expense, among other enterprises, of Dr. Schweinfurth's recent researches in Socotra.

MR. W. S. W. VAUX, F. R. S., a numismatist and Oriental scholar, and Secretary of the Royal Asiatic Society, is dead, at the age of sixty-seven years.

M. HENRI TRESCA, an eminent French physicist and engineer, died in June, in the seventieth year of his age. He filled the chair of Industrial Mechanics in the Conservatoire des Arts et Métiers, and was the author of works on "Applied Mechanics" and the "Flowing of Liquids." He was elected a member of the French Academy in 1872.

PROFESSOR A. W. EKLUND, a distinguished Swedish physicist, has recently died at Lund, aged ninety years.

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